Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

TECHNICAL SERIES NO. 19.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

I. THE PARASITES REARED OR SUPPOSED TO HAVE BEEN REARED FROM THE EGGS OF THE GIPSY MOTH.

By L. O. HOWARD, Ph. D.

II. DESCRIPTIONS OF CERTAIN CHALCIDOID PARASITES.

By J. C. CRAWFORD, *Assistant Curator, Division of Insects, United States National Museum.*

III. INVESTIGATIONS INTO THE HABITS OF CERTAIN SARCOPHAGIDÆ.

By T. L. PATTERSON, *Assistant in Biology, Sheffield Scientific School, Yale University*

WITH AN INTRODUCTION

By W. F. FISKE, *In Charge of Gipsy Moth Parasite Laboratory, Bureau of Entomology.*

IV. THE CHALCIDOID GENUS PERILAMPUS AND ITS RELATIONS TO THE PROBLEM OF PARASITE INTRODUCTION.

By HARRY S. SMITH, *Expert.*

V. EXPERIMENTAL PARASITISM: A STUDY OF THE BIOLOGY OF LIMNERIUM VALIDUM (CRESSON).

By P. H. TIMBERLAKE, A. M., *Agent and Expert, Gipsy Moth Parasite Laboratory.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Entomologist and Assistant Chief of Bureau.*
E. B. O'LEARY, *Chief Clerk and Executive Assistant.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
————————, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
A. F. BURGESS, *in charge of gipsy moth and brown-tail moth investigations.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

GIPSY MOTH AND BROWN-TAIL MOTH INVESTIGATIONS.

A. F. BURGESS, *in charge.*

D. M. ROGERS, *assistant in charge of gipsy-moth quarantine.*
L. H. WORTHLEY, *agent.*
C. H. T. TOWNSEND, S. S. CROSSMAN, C. W. COLLINS, F. H. MOSHER, R. W. GLASER, REGINALD WOOLDRIDGE, J. J. CULVER, and C.W. STOCKWELL, *entomological assistants.*
J. N. SUMMERS, J. W. CHAPMAN, J. B. SCHAFFNER, Jr., H. A. PRESTON, W. B. TURNER, C. E. HOOD, J. J. PILLSBURY, H. W. ALLEN, R. T. WEBBER, D. W. JONES, and JOHN W. BRADLEY, *scientific assistants.*
G. E. CLEMENT, WILLIS MUNRO, and D. O. INGALL, *assistants in forest management.*

PREFACE.

In the course of more than three years' work with the parasites and natural enemies of the gipsy moth and brown-tail moth, nearly all imported from Europe or Japan, it has been necessary to work with a number of species new to science and to make the most careful life-history observations upon all the species concerned in order to ascertain points of possible importance in the practical handling of the material. It is proposed in this Technical Series No. 19 to include a series of short papers giving some of the systematic and biological results of this work, the practical deductions for the most part being reserved for consideration in the bulletins of the general series.

Technical Series No. 12, Part VI, entitled "A Record of Results from Rearings and Dissections of Tachinidae," by Charles H. T. Townsend, published September 18, 1908, really should have started this Technical Series No. 19, since it directly concerns itself with results of work at the gipsy-moth parasite laboratory.

The laboratory in question, it should be stated, is now stationed at Melrose Highlands, Mass. (No. 17 East Highland Avenue). It is conducted with the cooperation of the State of Massachusetts and the United States Department of Agriculture.

L. O. Howard.

January 28, 1910.

CONTENTS.[1]

	Page.
The parasites reared or supposed to have been reared from the eggs of the gipsy moth.....*L. O. Howard*..	1
Introductory.....	1
Family Encyrtidæ.....	2
Subfamily Encyrtinæ.....	2
Tribe Mirini.....	2
Genus *Schedius*.....	2
Genus *Tyndarichus*.....	5
Subfamily Eupelminæ.....	7
Tribe Eupelmini.....	7
Genus *Anastatus*.....	7
Family Pteromalidæ.....	8
Subfamily Sphegigasterinæ.....	8
Tribe Pachyneurini.....	8
Genus *Pachyneuron*.....	8
Family Eulophidæ.....	9
Subfamily Elachertinæ.....	9
Tribe Elachertini.....	9
Genus *Atoposomoidea*.....	9
Subfamily Aphelininæ.....	11
Tribe Aphelinini.....	11
Genus *Perissopterus*.....	11
Family Proctotrypidæ.....	12
Subfamily Scelioninæ.....	12
Tribe Telenomini.....	12
Genus *Telenomus*.....	12
Descriptions of certain chalcidoid parasites.....*J. C. Crawford*..	13
Introduction.....	13
Family Chalcididæ.....	13
Subfamily Chalcidinæ.....	13
Tribe Chalcidini.....	13
Genus *Chalcis*.....	13
Family Perilampidæ.....	20
Genus *Perilampus*.....	20
Family Pteromalidæ.....	21
Subfamily Pteromalinæ.....	21
Tribe Pteromalini.....	21
Genus *Hypopteromalus*.....	21
Family Eulophidæ.....	22
Subfamily Entedoninæ.....	22
Tribe Entedonini.....	22
Genus *Pleurotropis*.....	22
Subfamily Eulophinæ.....	24
Tribe Eulophini.....	24
Genus *Dimmockia*.....	24

[1] The five papers constituting this bulletin were issued in separate form on Jan. 28 and Apr. 30, 1910, Mar. 22, 1911, and Apr. 22 and May 29, 1912, respectively.

Page.
Investigations into the habits of certain Sarcophagidæ.....*T. L. Patterson*.. 25
Introduction (by W. F. Fiske)..... 25
General conditions..... 27
Collection of gipsy-moth pupæ for maggots of Sarcophagidæ..... 27
Experiments with adult Sarcophagidæ..... 29
Experiments with first-stage maggots on living and dead material..... 30
Relation of decomposition to oviposition..... 30
Conclusion..... 31
The chalcidoid genus *Perilampus* and its relations to the problem of parasite introduction.....*Harry S. Smith*.. 33
Introductory..... 33
Biology of *Perilampus hyalinus* Say..... 34
Oviposition..... 37
Reproductive capacity..... 39
Description of planidium..... 39
Habits of planidium..... 41
Life as a parasite of *Varichæta*..... 42
As a parasite of *Limnerium validum* Cresson..... 43
As a parasite of summer-issuing Hymenoptera..... 44
As a parasite of other hosts..... 45
Later larval stages..... 45
Pupation..... 47
Food habits of the adult..... 48
Longevity and oögenesis..... 49
Length of life cycle and influence of temperature..... 49
Effect of parasitism upon host..... 51
Percentage of parasitism..... 52
Superparasitism..... 53
Perilampus versus *Perilampus*..... 53
Perilampus versus *Dibrachys*..... 55
Perilampus, "species A"..... 55
Development of *Orasema*..... 57
Planidium of *Orasema viridis* Ashmead..... 59
Relationship of Eucharidæ and Perilampidæ..... 59
Rhipiphorus and other coleopterous parasites..... 60
Host relations of the genus *Perilampus*..... 61
Rearing records of *Perilampus hyalinus* at the laboratory..... 61
Other American rearing records of *Perilampus*..... 62
European rearing records of *Perilampus*..... 64
European species of *Perilampus* reared at the laboratory..... 65
Résumé of host relations of the genus..... 66
The economic aspects..... 67
Experimental parasitism: A study of the biology of *Limnerium validum* (Cresson).....*P. H. Timberlake*.. 71
Introduction..... 71
Experiments..... 72
General methods of experimentation..... 72
Behavior of *Limnerium validum* (Cresson) in confinement..... 73
Limnerium validum as a parasite of *Euproctis chrysorrhœa* (Linnæus).. 73
First experiment..... 74
Second experiment..... 74
Amœbocytosis as a protective reaction of the host..... 75
Adaptation of parasite to host..... 76
Further experiments with *Euproctis chrysorrhœa*..... 77

Experimental parasitism—Continued.
Experiments—Continued. Page.
Limnerium validum as a parasite of *Malacosoma americana* (Fabricius). 78
Results of experiments as determined by dissection. 78
Emergence of adults of *Limnerium* from reproduction. 79
Length of the stages in the life history of *Limnerium*. 80
A possibly normal parasite of *Malacosoma*. 80
Limnerium validum as a parasite of *Notolophus antiquus* (Linnæus). 81
Limnerium validum as a parasite of *Porthetria dispar* (Linnæus). 82
Experiments with other hosts. 83
Notes on development and anatomy of the larva. 83
The egg. 83
The first-stage larva. 84
Description of the newly hatched larva. 84
Function of the tail appendage. 85
Appearance of older larvæ. 85
Notes on the anatomy of the larva. 86
The second-stage larva. 87
The third-stage larva. 87
Description of the full-grown larva. 87
Feeding habits of the imprisoned larva. 88
Respiration of the larva in the third stage. 89
The cocoon. 90
Results of the dissections of *Hyphantria* during the fall of 1910. 90
General summary. 91
Bibliography. 92
Index. 93

ILLUSTRATIONS.

Page.
FIG. 1. *Schedius kuvanæ*: Female. 4
2. *Schedius kuvanæ*: Antennæ of male and female. 5
3. *Schedius kuvanæ*: Fore and hind wings of female. 5
4. *Tyndarichus navæ*: Antennæ of male and female. 6
5. *Tyndarichus navæ*: Fore and hind wings of female. 6
6. *Anastatus bifasciatus*: Female. 7
7. *Atoposomoidea ogimæ*: Female and details. 9
8. *Chalcis ovata*, female: Head, showing carina at front of malar space. 15
9. *Chalcis ovata*, female: Ventral view of hind coxa, showing tubercle. 15
10. *Chalcis ovata*, female: Hind femur and tibia, showing markings. 15
11. *Chalcis robusta*, female: Hind femur and tibia, showing markings. 15
12. *Chalcis incerta*, female: Hind femur and tibia, showing markings. 16
13. *Chalcis fiskei*, female: Hind femur and tibia, showing markings. 16
14. *Chalcis fiskei*, female: Head, showing carina at front of malar space. 16
15. *Chalcis obscurata*, female: Hind femur and tibia, showing markings. 17
16. *Chalcis obscurata*, female: Head, showing carina at front of malar space 17
17. *Chalcis flavipes*, female: Hind femur and tibia, showing markings. 18
18. *Chalcis flavipes*, female: Head, showing carina at front of malar space. 18
19. *Chalcis minuta*, female: Hind femur and tibia, showing markings. 18
20. *Chalcis minuta*, female: Hind femur, inner side, showing tubercle near base. 18

Page.

21. *Chalcis minuta*, female: Head, showing carina at front of malar space.. 18
22. *Chalcis paraplesia*, female: Hind femur and tibia, showing markings.. 19
23. *Chalcis paraplesia*, female: Head, showing carina at front of malar space 19
24. *Perilampus hyalinus:* Planidium, ventral view..... 40
25. *Perilampus hyalinus:* Planidium, dorsal view..... 40
26. Pupa of *Varichæta aldrichi*, parasitized by *Perilampus hyalinus;* pupa of same unparasitized; planidium of *Perilampus hyalinus*, before and after feeding..... 46
27. *Perilampus hyalinus:* Mature larva..... 47
28. *Perilampus hyalinus:* Fresh pupa..... 48
29. *Perilampus hyalinus:* Pupa just previous to eclosion..... 48
30. *Perilampus*, "species A": Planidium, ventral view..... 56
31. *Perilampus*, "species A": Planidium, dorsal view..... 56
32. *Limnerium validum:* Adult female, abdomen of male, metascutum, cocoon..... 72
33. *Limnerium validum:* Egg..... 83
34. *Limnerium validum:* Eclosion of larva..... 83
35. *Limnerium validum:* First-stage larva, newly hatched..... 84
36. *Limnerium validum:* First-stage larva of large size, showing silk glands and nervous system..... 85
37. *Limnerium validum:* Mouthparts of first-stage larva..... 86
38. *Limnerium validum:* Second-stage larva..... 87
39. *Limnerium validum:* Mouthparts of second-stage larva..... 87
40. *Limnerium validum:* Third-stage larva..... 88
41. *Limnerium validum:* Anterior view of head of third-stage larva, showing mouthparts..... 88

ERRATA.

Page 1, line 3, for *On some* read *The.*
Page 18, line 4, after *German* insert period.
Page 68, line 18, omit comma after *parasites.*
Page 68, line 19, omit comma after *encountered.*
Page 72, line 9, for *Hypantria* read *Hyphantria.*
Page 76, line 23, for *incapsulated* read *encapsulated.*
Page 76, line 24, after *always* omit comma.
Page 76, line 25, after *frequently* insert comma.

TECHNICAL SERIES, NO. 19, PART I.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

I. THE PARASITES REARED OR SUPPOSED TO HAVE BEEN REARED FROM THE EGGS OF THE GIPSY MOTH.

By L. O. HOWARD, PH. D.

ISSUED JANUARY 28, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
Chas. J. Gilliss, *Chief Clerk.*
F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, H. S. Smith, H. L. Viereck, W. R. Thompson, C. W. Collins, T. L. Patterson, R. Wooldridge, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, A. L. Connolly, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants*

PREFACE TO BULLETIN.

In the course of rather more than three years' work with the parasites and natural enemies of the gipsy moth and brown-tail moth, nearly all imported from Europe or Japan, it has been necessary to work with a number of species new to science and to make the most careful life-history observations upon all the species concerned in order to ascertain points of possible importance in the practical handling of the material. It is proposed in this Technical Series No. 19 to include a series of short papers giving some of the systematic and biological results of this work, the practical deductions for the most part being reserved for consideration in bulletins of the general series.

The present paper, therefore, forms the first of such a series. It describes several new egg-parasites and gives some consideration to others already described. It also includes a brief consideration of other forms supposed to have been reared from gipsy moth eggs.

Technical Series No. 12, Part VI, entitled "A Record of Results from Rearings and Dissections of Tachinidæ," by Charles H. T. Townsend, published September 18, 1908, really should have started this Technical Series No. 19, since it directly concerns itself with results of work at the gipsy moth parasite laboratory.

The laboratory in question, it should be stated, is now stationed at Melrose Highlands, Mass. (No. 17 East Highland avenue). It is conducted under the joint cooperation of the State of Massachusetts and the U. S. Department of Agriculture. The rental of the building, all construction work, nonexpert assistance, and the expendable supplies, together with the compensation of foreign agents, are charged to the State of Massachusetts. The Bureau of Entomology of the Department of Agriculture is charged with the salaries and expenses of all expert assistants and with all nonexpendable supplies and apparatus.

L. O. H.

CONTENTS.

	Page.
Introductory	1
Family Encyrtidæ	2
Subfamily Encyrtinæ	2
Tribe Mirini	2
Genus Schedius	2
Genus Tyndarichus	5
Subfamily Eupelminæ	7
Tribe Eupelmini	7
Genus Anastatus	7
Family Pteromalidæ	8
Subfamily Sphegigasterinæ	8
Tribe Pachyneurini	8
Genus Pachyneuron	8
Family Eulophidæ	9
Subfamily Elachertinæ	9
Tribe Elachertini	9
Genus Atoposomoidea	9
Subfamily Aphelininæ	11
Tribe Aphelinini	11
Genus Perissopterus	11
Family Proctotrypidæ	12
Subfamily Scelioninæ	12
Tribe Telenomini	12
Genus Telenomus	12

ILLUSTRATIONS.

		Page.
Fig. 1.	*Schedius kuvanæ:* Female	4
2.	*Schedius kuvanæ:* Antennæ of male and female	5
3.	*Schedius kuvanæ:* Fore and hind wings of female	5
4.	*Tyndarichus navæ:* Antennæ of male and female	6
5.	*Tyndarichus navæ:* Fore and hind wings of female	6
6.	*Anastatus bifasciatus:* Female	7
7.	*Atoposomoidea ogimæ:* Female and details	9

U. S. D. A., B. E. Tech. Ser. 19, Pt. I. Issued January 28, 1910.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

On Some Parasites Reared or Supposed to have been Reared from the Eggs of the Gipsy Moth.

By L. O. Howard, Ph. D.

INTRODUCTORY.

No native American egg-parasites have ever been reared from the eggs of the gipsy moth (*Porthetria dispar* L.) since its introduction into this country in the late sixties. This seems strange, since native Lepidopterous eggs are very frequently attacked by egg-parasites of several genera, notably by *Trichogramma* and *Telenomus*, as well as occasionally by *Anastatus* and *Ooencyrtus*. Nonparasitism of *dispar* by native species is probably due to the character of its egg-mass, which is so compact and so thoroughly protected by the scales of the parent as possibly to disguise its character from species unacquainted with it for many generations, while actual experiments with *Trichogramma* seem to show that it is unable to pierce the shell of the gipsy moth egg.

In the course of the extensive importations of parasites of this species from Europe and Japan, however, carried on cooperatively by the State of Massachusetts and the Bureau of Entomology of the U. S. Department of Agriculture, several primary and secondary parasites have been reared from these eggs at the Gipsy Moth Parasite Laboratory at Melrose Highlands, Mass., where they have been studied in greater or less numbers by Mr. W. F. Fiske, of the Bureau of Entomology, in charge of the laboratory, and by the corps of assistants working under his direction, and have in some cases been colonized in the open. In the following pages descriptions are given of the new forms, together with brief notes concerning their habits, the notes being the result of the observations of Mr. Fiske and assistants. Only two of the species, namely, *Anastatus bifasciatus* Fonsc. and *Schedius kuvanæ* How., appear to be of primary importance, but it is obvious that once acclimatized these two species will perform a very considerable part in the reduction in numbers of the gipsy moth in the United States.

The parasites so far reared have all come from Japan, southern Russia, and Hungary. The *Anastatus* has a wider range, occurring

in many parts of Europe, but has other hosts. Shipments of *dispar* eggs received at the Parasite Laboratory from Switzerland and northern Germany have given out no parasites whatever. Silvestri states that he has never been able to secure parasites from the eggs of *dispar* in Italy, but there is a reasonable chance that he did not keep his material long enough to have secured the summer-issuing forms had they been present. There is no evidence as yet that gipsy moth egg-parasites occur in western Europe—that is, France or Spain.

Other insects are occasionally sent to this country accidentally with these egg-masses, one of them, a small Dermestid beetle, really feeding upon the eggs. This insect was found in considerable numbers in a large shipment of *dispar* eggs, sent by Prof. Trevor Kincaid from Japan, which were collected after the caterpillars had emerged. This species has been examined by Mr. E. A. Schwarz, who states that it is probably an undescribed species and genus of the group Attageni. The larvæ of *Anthrenus verbasci* L. are constantly found in the old cocoon masses of the white-marked tussock moth (*Hemerocampa leucostigma* S. & A.) in this country and under the batches of eggs already hatched, where they are engaged in feeding upon the dry remains of pupæ and eggs. The writer [a] has pointed out that these larvæ also eat the healthy eggs, and that *Trogoderma tarsale* Melsh., another Dermestid, has the same habit. This has since been seen to be the case with the white-marked tussock moth in Massachusetts, and one of these species has several times been reported as destroying the eggs of the gipsy moth in Massachusetts.

The cocoons of *Glyptapanteles* have also been sent in on bits of bark attached to the egg-masses; and other small miscellaneous insects, including several species of small moths which had sought the protection of the egg-masses for pupation, have come in, indicating not only the great possibility of error in rearing insects from large masses of material, but also the necessity for great care to avoid the introduction of new insect pests.

Family ENCYRTIDÆ Walker.

Subfamily ENCYRTINÆ Howard.

Tribe MIRINI Ashmead.

Genus SCHEDIUS, new genus.

Female.—Mandibles broad at apex, very obscurely tridentate; outer tooth rather short, acute; middle tooth rounded, inner tooth flat and with a straight edge. Antennæ inserted just above border of the mouth; facial depression well marked; clypeus well rounded and elevated; vertex rather narrow, head well produced in front;

[a] Technical Series No. 5, Bur. Ent., U. S. Dept. Agr., p. 46, 1897.

ocelli at angles of slightly acute-angled triangle, lateral ocelli nearer eye-border than to each other; occipital margin somewhat rounded; eyes large, well rounded, rigid (keeping their shape after death), very faintly hairy. Antennal scape slender, subcylindrical; pedicel nearly three times as long as broad; funicle subcylindrical, joint 1 short, about one-half length of pedicel, remaining joints increasing slightly in length and width to club, except that joint 6 is slightly shorter than 5; club ovate, flattened, nearly as long as last three funicle joints together, basal joint longest. Body stout; mesonotal axillæ well separated at tips; mesoscutellum well rounded; abdomen shorter than thorax, short-ovate. Wings long and broad; marginal vein punctiform; stigmal rather long, slender, slightly enlarged at tip, extending into the wing-disc at an angle of about 35 degrees with the costa; postmarginal evident, but not so long as stigmal; wing-disc with an oblique hairless streak extending from stigmal vein toward the base of the wing; hind wings rather narrow, but densely and uniformly ciliate.

Male.—Differs from female principally in the shorter abdomen and in the antennæ. Antennæ with scape slightly widened below; pedicel obconical, very slightly longer than width at tip; first funicle joint slightly longer than pedicel; funicle joints 1 to 5 subequal in length and width, 6 somewhat shorter; all funicle joints somewhat convex on outer side, nearly straight on inner side; club ovate, rather broadly flattened, somewhat longer than funicle joints 5 and 6 together; all of flagellum beyond pedicel rather closely furnished with hairs averaging about two-thirds the length of the respective sclerites that bear them.

Type.—The following species:

SCHEDIUS KUVANÆ, new species.

(Figs. 1–3.)

Female.—Length, 0.99^{mm}; expanse, 2.39^{mm}; greatest width of fore wing, 0.43^{mm}. Vertex and cheeks very faintly shagreened; mesoscutum nearly smooth, shining, with minute, rather sparse punctures; mesoscutellum densely and rather coarsely shagreened, well rounded at tip; propleura very faintly shagreened, somewhat shining. General color black; mesoscutellum with a bronzy luster; trochanters, tips of femora, apical half or a little more of front and middle and hind tibiæ yellowish; all tarsi lighter; antennæ dark brown; dark parts of the legs more brown than black. Wings hyaline.

Male.—Length, 0.9^{mm}; expanse, 2.28^{mm}; greatest width of fore wing, 0.43^{mm}. Resembles female, except that the flagellum of the antenna is light brown, and except for the structural characters mentioned in the generic diagnosis.

Described from numerous male and female specimens reared September, 1908, at the Gipsy Moth Parasite Laboratory of the State of

Massachusetts and the Bureau of Entomology, at Melrose Highlands, Mass., from the eggs of *Porthetria dispar* received from Tokyo, Japan, from Prof. S. I. Kuwana, Entomologist of the Imperial Agricultural Experiment Station at Nishigahara, Tokyo, after whom the species is named in partial recognition of his great services to the United States in sending parasites from Japan.

Type.—No. 12158, U. S. National Museum; Gipsy Moth Laboratory No. 1698.

This species appears to be an important parasite of the gipsy moth. It has been imported in very large numbers through the courtesy of Professor Kuwana. The great majority of the specimens have been dead upon arrival, but small numbers have emerged living at the Gipsy Moth Parasite Laboratory at Melrose Highlands. The species appears to be more common in the vicinity of Tokyo than

FIG. 1.—*Schedius kuvanæ:* Female. Highly magnified. (Original.)

in other parts of Japan. This parasite in the field issues from *dispar* eggs in the autumn after they have been deposited. For some reason it has not been reared freely from Japanese eggs collected and forwarded during the winter. The possible inference that it does not hibernate in the eggs of this host in Japan is not in accord with its behavior in America. There is ample time for two and possibly three generations in the same autumn after the gipsy moth has laid its eggs. The species is easily controlled in the laboratory, as determined by Mr. Fiske, and more than twenty thousand have been reared and liberated from a total importation of about twenty living individuals. The early stages have been worked out at the laboratory by Messrs. Fiske and H. F. Smith, and are very remarkable. It attacks the eggs of its host when freshly deposited and with equal

freedom those which contain the fully developed caterpillar all ready to hatch.

Genus TYNDARICHUS, new genus.

Female.—Mandibles like those of *Schedius*. Antennæ short; scape rather short, with a rather broad leaflike extension below; pedicel long, obconical, two and one-half times as long as width at tip and half as long as funicle; first funicle joint narrower than tip of pedicel and rather shorter than broad; funicle joints 2, 3, and 4 each about as long as 1, but gradually widening; 5 and 6 somewhat longer and considerably wider, thus making the width increase from 1 to 6; club very broad, somewhat flattened, having three segments subequal in length, but with the dividing sutures slightly oblique, tip obliquely truncate from a point immediately before the last suture; flagellum with sparse hairs, and scape and pedicel with a few bristles. Body short, stout, resembling *Schedius* in general appearance. Antennæ inserted slightly above mouth border; facial depression and clypeus resembling *Schedius;* vertex narrower than with *Schedius*, but ocelli placed in the same manner; occipital margin acute; eyes naked, not rigid (falling in after death). Axillæ of mesonotum barely meeting at tip; abdomen flattened above, triangular, nearly as long as thorax. Fore wings broad; disc closely ciliate though not so densely as with *Schedius*, oblique hairless line below stigma faintly indicated, but the entire disc below submarginal vein only sparsely ciliate; marginal vein punctiform, stigmal much as with *Schedius;* submarginal vein with a pronounced and curious break beyond middle as illustrated in figure 5; hind wings broader than with *Schedius*.

FIG. 2.—*Schedius kuvanæ:* ♂, Antenna of male; ♀, antenna of female. Highly magnified. (Original.)

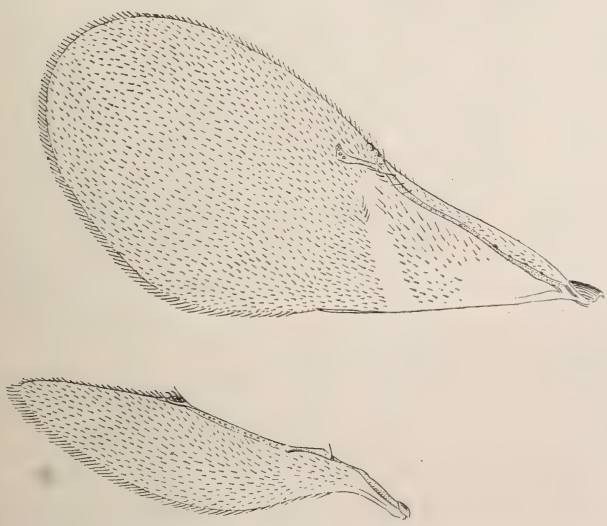

FIG. 3.—*Schedius kuvanæ:* Fore and hind wings of female. Highly magnified. (Original.)

Male.—Body short, stout; mesonotum highly arched; abdomen flat, broadly ovate. Antennæ long, submoniliform, ventral outline of funicle joints nearly straight, dorsal outlines somewhat rounded; scape short, subcylindrical, very slightly widened ventrally; pedicel shorter than first funicle joint; all funicle joints subequal in length and width, the sixth rather shorter; club slightly flattened, long-ovate, pointed at tip, one and one-half times longer than sixth funicle joint; the whole flagellum beyond pedicel rather abundantly furnished with long, slightly curving bristles, having no marked tendency to form definite whorls, each bristle about as long as its sclerite.

FIG. 4.—*Tyndarichus navæ: a*, Antenna of female; *b*, club of same, from below; *c*, antenna of male. Highly magnified. (Original.)

Type.—The following species:

TYNDARICHUS NAVÆ, new species.

(Figs. 4, 5.)

Female.—Length, 1.08^{mm}; expanse, 2.19^{mm}; greatest width of fore wing, 0.39^{mm}. Entire body black, shining; head and mesonotum very faintly shagreened; vertex and cheeks with steel-blue reflections; mesoscutellum with coppery reflections; antennæ dark brown, with light brown pile; all legs dark brown, nearly black except at tips of tibiæ and all tarsi.

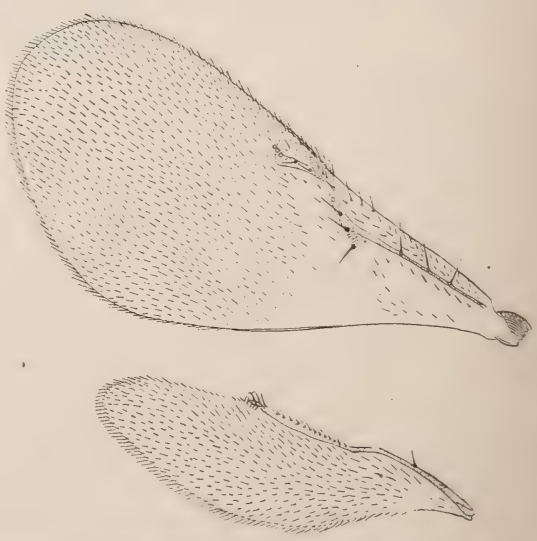

FIG. 5.—*Tyndarichus navæ:* Fore and hind wings of female. Highly magnified. (Original.)

Male.—Length, 0.93^{mm}; expanse, 2.19^{mm}; greatest width of fore wing, 0.44^{mm}. Differs from female, aside from characters mentioned in generic description, very slightly. Antennæ brownish, with black

hairs. General appearance of body more opaque than with the female and metallic reflections less distinct; leg coloration identical.

Described from seven female and four male specimens reared from the eggs of *Porthetria dispar*, June, July, and August, received from U. Nawa, Gifu, Japan, after whom the species is named.

Type.—No. 12159, U. S. National Museum; Gipsy Moth Laboratory Nos. 1625, 1020, and 1039.

This parasite has also been imported from Japan in eggs collected by Professor Kuwana, and seems to follow *Schedius* in distribution in Japan. It is very much less common, but varies in abundance in different lots of eggs. Unlike *Schedius*, it has been reared freely from the eggs collected and forwarded during the winter, emerging at various times in the spring and summer. So far as indicated by a considerable number of dissections made by Messrs. Fiske and

FIG. 6.—*Anastatus bifasciatus:* Female. Highly magnified. (Original.)

Smith, it is invariably secondary. Its host is usually *Schedius*, occasionally *Pachyneuron*, and possibly *Anastatus*.

Subfamily EUPELMINÆ Howard.

Tribe EUPELMINI Ashmead.

Genus ANASTATUS Motschulsky.

ANASTATUS BIFASCIATUS (Fonscolombe).

(Fig. 6.)

Cynips bifasciata Fonscolombe.
Eupelmus bifasciatus Förster, 1860.
Eupelmus bifasciatus Wachtl, 1882 (from eggs of *Ocneria dispar*).

This very widespread parasite is an important enemy of the gipsy moth. It has been reared at the Parasite Laboratory at Melrose

Highlands by Mr. Fiske and assistants from egg-masses received from all parts of Japan, but more commonly from those collected in Fukuoka, these egg-masses having been sent in by several of the energetic Japanese correspondents of the Bureau, but principally by Mr. U. Nawa and Prof. S. I. Kuwana. It has also been reared from eggs sent from the Crimea by Prof. S. Mokshetsky, and in especial abundance from eggs sent from Hungary by Prof. J. Jablonowski. The species appears to be much more common in European countries, but is apparently local in its European distribution. Dalla Torre records it from France and from lower Austria. Many thousands of specimens of this species have been reared at the Parasite Laboratory. It attacks the egg of *dispar* very shortly after the latter is deposited, and requires a full year for a generation—a fact which, while it would seem to reduce its possible value as an effective parasite of the gipsy moth, really enhances it as an introduced species, since it is independent of other insects for alternate hosts at seasons when eggs of the gipsy moth are not available. The accompanying figure was drawn from a museum specimen. In life the abdomen is not sunken dorsally.

Family PTEROMALIDÆ Ashmead.

Subfamily SPHEGIGASTERINÆ Ashmead.

Tribe PACHYNEURINI Ashmead.

Genus PACHYNEURON Walker.

PACHYNEURON GIFUENSIS Ashmead.

Pachyneuron gifuensis Ashmead, Journ. N. Y. Ent. Soc., XII, No. 3, p. 158, September, 1904.

This species, described by Ashmead as above, was part of a collection referred to the U. S. National Museum some years ago by Professor Mitsukuri, of Tokyo. It has recently been imported from Japan in eggs of *dispar* collected by Prof. S. I. Kuwana, and is apparently common in the vicinity of Tokyo. In habits it is like *Tyndarichus navæ*, as determined by Messrs. Fiske and Smith at the Parasite Laboratory, but it is a little less common and issues in the spring. It is a hyperparasite, and attacks *Schedius kuvanæ* and *Tyndarichus navæ* as well; in the first instance being secondary and in the other instance tertiary. In one instance at the laboratory it was reared from an egg which originally contained *Anastatus bifasciatus*. The type and two other specimens were reared by Mr. Y. Nawa from an aphis at Gifu, Japan, undoubtedly parasitic on some primary parasite of the Aphidid.

Family EULOPHIDÆ Ashmead.

Subfamily ELACHERTINÆ Ashmead.

Tribe ELACHERTINI Ashmead.

Genus ATOPOSOMOIDEA, new genus.

Female.—Apparently this genus comes near *Atoposoma* Masi, as the proposed name suggests, and is distinguished chiefly by the solid thorax, naked eyes, somewhat less elevated vertex, slightly different dentation of the mandibles, low insertion of the antennæ, different proportions of the antennal sclerites, and greater length of postmarginal vein—all of which are indicated in the accompanying illustration (fig. 7). *Atoposoma* is closely related to *Zagrammosoma* Ashmead, also parasitic on a Lepidopterous larva.

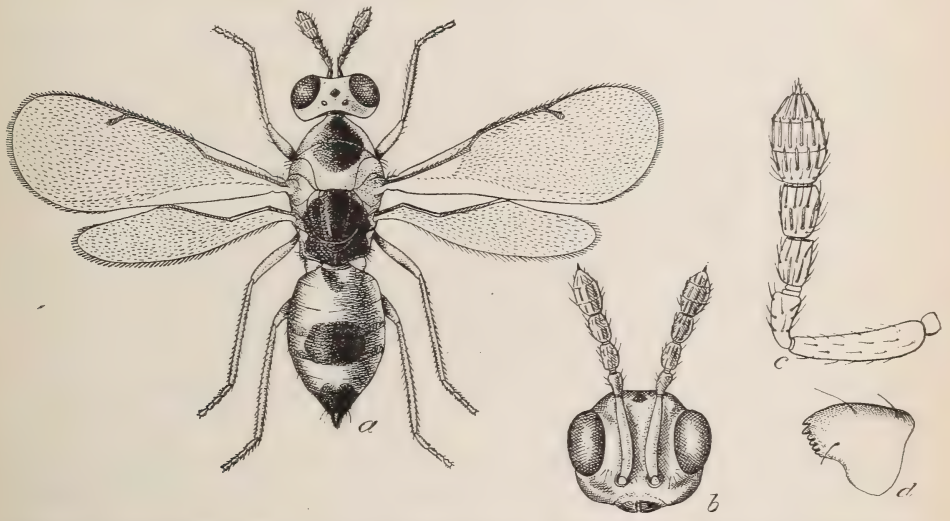

FIG. 7.—*Atoposomoidea ogimæ: a*, Female; *b*, head of same, anterior aspect; *c*, antenna of same; *d*, mandible of same. *a*, Very much enlarged; *b–d*, highly magnified. (Original.)

Male.—Differs from female in its shorter antennæ, which are furnished with rather dense pile which is shorter than with female. It also has a shorter abdomen.

Type.—The following species:

ATOPOSOMOIDEA OGIMÆ, new species.

(Fig. 7.)

Female.—Length, 1.65^{mm}; expanse, 2.66^{mm}; greatest width of fore wing, 0.5^{mm}. Pronotum and entire mesonotum finely shagreened. Mesopleura also finely shagreened. General color lemon-yellow. Head with a large, black occipital spot; a large, nearly circular, black spot on pronotum and mesonotum, divided in about its middle by the pronotal suture; central portion of mesoscutellum black, and

the sides as well, below middle; metanotum black; abdomen with a black, rounded spot dorsally just below middle, abdomen also black at tip; antennæ brownish, with a whitish pile; all legs light yellow.

In the markings the species is extremely variable. A frequent variation from what we may call the typical markings as shown in the illustration, is the absence of the black spot on mesoscutellum, although sometimes it is represented by a minute central dot; the occipital black spot is frequently lacking; the pronotal and mesoscutal spots frequently become greatly reduced in size. On the other hand, in many specimens the black spots become greatly enlarged so as to make black almost the predominant color of the insect.

Male.—Length, 1.26^{mm}; expanse, 2.43^{mm}; greatest width of fore wing, 0.43^{mm}. Antennæ yellowish, with abundant, long, white pile. Color as with female, except that entire apical half of dorsum of abdomen is black, and entire pronotum is black. There is almost the same range of variation in size of black spots as with the female.

Described from 43 female and 8 male specimens reared from cocoons of *Glyptapanteles japonicus* Ashmead, received from Trevor Kincaid during the summer of 1908 from various localities in Japan, and from other cocoons of the same species received from S. I. Kuwana during the summer of 1909 from different localities in Japan. Named after Prof. G. Ogima, Assistant Entomologist, Kyushiu Experiment Station, Kumamoto, Japan, in recognition of his valuable services.

Type.—No. 12681, U. S. National Museum; Gipsy Moth Laboratory Nos. 1623 and 1074.

There is a single female of this species, labeled "Kumamoto, Japan, reared 10th of May, 1907, by G. Ogima, egg-parasite of *P. dispar.*" This specimen was not sent to the writer by Professor Ogima himself directly, but either through Professor Kuwana or Mr. Kincaid, and it is the receipt of this specimen which justifies the description of this new genus and species in a paper on the egg-parasites of the gipsy moth. Very large numbers of this parasite, however, have been reared at the Parasite Laboratory at Melrose Highlands, by Mr. Fiske, from the cocoons of the *Glyptapanteles*, and it is very possible that a mistake has arisen in Japan through the rearing of this species apparently from an egg-mass of *dispar* which had been laid over a mass of *Glyptapanteles* cocoons. Similar instances have occurred before, notably in the case of Ashmead's *Ablerus clisiocampæ*, which apparently came from an egg-mass of *Clisiocampa* but in reality from *Chionaspis furfura* on the bark of the twig under the egg-mass of the Lepidopterous insect. Similarly the writer's *Isodromus iceryæ* was apparently reared by Mr. D. W. Coquillett from egg-masses of *Icerya purchasi* but in reality came from a *Chrysopa*

cocoon hidden among the egg-masses and so covered with wax as probably to be indistinguishable.

Several species of Elachertines of this general type, including at least one undescribed genus in addition to *Atoposoma* and *Zagrammosoma*, have been reared from Microlepidopterous larvæ. The first one that the writer ever saw was reared from *Lithocolletis fitchella* in Washington in 1879. Others were reared from leaf-miners from Florida, but none of these striking forms was described until Ashmead[a] described the genus *Hippocephalus* for a species, *multilineatus*, reared by Mr. C. L. Marlatt from *Lithocolletis ornatella*. On account of the preoccupation of the name *Hippocephalus*, Ashmead, in his monograph of the Chalcidoidea, changed the name to *Zagrammosoma*. Masi's type of *Atoposoma* (*A. variegatum*) fed in the larval state exteriorly on a larva of the Lepidopter, *Œcophyllembius neglectus*. The present genus, *Atoposomoidea*, appears to be the first Chalcidid of this markedly beautiful and peculiar facies to have been reared from a Braconid cocoon, and we must assume from the great numbers in which these rearings have been made that the habit is normal for this species.

Subfamily APHELININÆ Howard.

Tribe APHELININI Ashmead.

Genus PERISSOPTERUS Howard.

PERISSOPTERUS JAVENSIS Howard.

Perissopterus javensis Howard, New Genera and Species of Aphelininae, Tech. Ser. 12, Pt. IV, Bur. Ent., U. S. Dept. Agr., Washington, p. 88, July 12, 1907.

The type series of this beautiful little parasite was reared in February, 1900, by A. Koebele from a scale insect of the genus *Tachardia* on an ornamental plant at Singapore, Straits Settlements. All of the other species of the genus have been reared invariably from scale insects and nothing else. A record of the issuance of *P. javensis* from gipsy moth eggs is therefore open to doubt, and one's first impression is that it must have come from some scale insect over which a *dispar* egg-mass had been laid. Nevertheless, according to Mr. Fiske, the single female submitted to the writer for determination came from a *dispar* egg received from Professor Kuwana from near Tokyo. The apparent great discrepancy between this statement and the previous records renders it desirable to give an explicit statement of the facts as observed by Mr. Fiske. From his original notes it is found that December 9, 1908, a lot of 250 egg-masses of *dispar*, collected in Tokyo November 5, 1908, by Professor Kuwana, was received. One of these egg-masses was thin, with the hairy covering badly weathered, and many of the eggs exposed. Critical examina-

[a] Bulletin 3, Kans. St. Exp. Sta., 1888.

tion of this mass indicated that 181 of the eggs were apparently healthy. Parasites had emerged from 108, while the dead or doubtful eggs numbered 35. Mr. Fiske thinks that the parasites that had emerged were probably *Schedius*. On December 14 the 35 eggs of the third category were assorted into those which appeared to contain parasites and those which were dead. They were emptied into a watch glass, and a single, small, living parasite (the *Perissopterus* under consideration) was found. Careful examination of the eggs showed two which had very small round holes in the side, from either of which the parasite might have come. These holes were smaller than those usually made by any of the other known parasites. These eggs were separated from the others, and on March 4 one of them was boiled in caustic potash (KOH) and its contents examined. Fragments of the pupal exuvium of a small Chalcidid different from that of any other parasite studied was found and mounted. There was no other indication of any other parasite in the egg, and the one which emerged appeared to have fed upon the caterpillars primarily. No parasite remains were found in the other pierced egg. The parasite found on December 14 was placed in a small vial with a variety of eggs, including some of *dispar* that contained larvæ of *Anastatus*, others that contained healthy *dispar* caterpillars, and some of the tussock moth. The *Perissopterus* (which was a female) lived for some days, but showed no interest in any of the eggs.

Family PROCTOTRYPIDÆ Ashmead.

Subfamily SCELIONINÆ Howard.

Tribe TELENOMINI Ashmead.

Genus TELENOMUS Haliday.

TELENOMUS, new species.

In the autumn of 1897 there was received from Prof. S. Mokshetsky, of Simferopol, Russia, a single specimen of a new species of *Telenomus*, which he reared during September, 1906, from the eggs of the gipsy moth. As probably Professor Mokshetsky will describe this species himself, it is given no name at this time. Curiously enough, it belongs to the same group of the genus to which *Telenomus cultratus* Mayr belongs much more closely than to any of the species reared from Lepidopterous eggs. *T. cultratus* lives both as larva and pupa in the eggs of the Pentatomidæ, from which it has been reared by Rogenhofer and Hofmann. This new species does not appear to be an important parasite of *dispar* eggs, since this is the only rearing known to us, and none has been recorded.

O

TECHNICAL SERIES, NO. 19, PART II.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY.
L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

II. DESCRIPTIONS OF CERTAIN CHALCIDOID PARASITES.

By J. C. CRAWFORD,
Assistant Curator, Division of Insects, U. S. National Museum.

ISSUED APRIL 30, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
Chas. J. Gilliss, *Chief Clerk.*
F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, H. S. Smith, H. L. Viereck, W. R. Thompson, C. W. Collins, T. L. Patterson, R. Wooldridge, P. H. Timberlake, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, A. L. Connolly, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants.*

CONTENTS.

	Page.
Introduction	13
Family Chalcididæ	13
Subfamily Chalcidinæ	13
Tribe Chalcidini	13
Genus Chalcis	13
Family Perilampidæ	20
Genus Perilampus	20
Family Pteromalidæ	21
Subfamily Pteromalinæ	21
Tribe Pteromalini	21
Genus Hypopteromalus	21
Family Eulophidæ	22
Subfamily Entedoninæ	22
Tribe Entedonini	22
Genus Pleurotropis	22
Subfamily Eulophinæ	24
Tribe Eulophini	24
Genus Dimmockia	24

ILLUSTRATIONS.

Page.

FIG. 8. *Chalcis ovata*, female: Head, showing carina at front of malar space.... 15
9. *Chalcis ovata*, female: Ventral view of hind coxa, showing tubercle.... 15
10. *Chalcis ovata*, female: Hind femur and tibia, showing markings..... 15
11. *Chalcis robusta*, female: Hind femur and tibia, showing markings..... 15
12. *Chalcis incerta*, female: Hind femur and tibia, showing markings..... 16
13. *Chalcis fiskei*, female: Hind femur and tibia, showing markings..... 16
14. *Chalcis fiskei*, female: Head, showing carina at front of malar space.... 16
15. *Chalcis obscurata*, female: Hind femur and tibia, showing markings.... 17
16. *Chalcis obscurata*, female: Head, showing carina at front of malar space. 17
17. *Chalcis flavipes*, female: Hind femur and tibia, showing markings..... 18
18. *Chalcis flavipes*, female: Head, showing carina at front of malar space.. 18
19. *Chalcis minuta*, female: Hind femur and tibia, showing markings..... 18
20. *Chalcis minuta*, female: Hind femur, inner side, showing tubercle near base..... 18
21. *Chalcis minuta*, female: Head, showing carina at front of malar space.. 18
22. *Chalcis paraplesia*, female: Hind femur and tibia, showing markings... 19
23. *Chalcis paraplesia*, female: Head, showing carina at front of malar space. 19

U. S. D. A., B. E. Tech. Ser. 19, Pt. II. Issued April 30, 1910.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

II. Descriptions of Certain Chalcidoid Parasites.

By J. C. Crawford,
Assistant Curator, Division of Insects, U. S. National Museum.

INTRODUCTION.

The new species described in this paper came from material imported from Japan and Europe for the purpose of rearing parasites of the gipsy moth and the brown-tail moth. The work of rearing these parasites is conducted at the Gipsy Moth Parasite Laboratory, now situated at Melrose Highlands, Mass.

In the study of these parasites a Zeiss binocular microscope has been used with magnifications of from 24 to 35. In cases where the description states that the series includes more than one specimen of each sex the description is drawn from one specimen of each sex, and any variations in the other specimens, which are designated as paratypes, are cited.

In considering the genus *Chalcis* it has been deemed desirable to display in a synoptic table not only all of the species of this genus which have been introduced purposely as parasites of the gipsy moth or the brown-tail moth or accidentally included in shipments of parasite material, but also all of the species of the genus known to occur in the United States. In the same way it has been deemed desirable to publish a table separating the common American form from the two species of the genus *Hypopteromalus* accidentally included in shipments of parasite material, and also to separate in a synoptic table the different Japanese species of the genus *Pleurotropis* which have three funicle joints. As pointed out, *P. atamiensis* belongs probably to an undescribed genus.

Family CHALCIDIDÆ Walker.

Subfamily CHALCIDINÆ Howard.

Tribe CHALCIDINI Ashmead.

Genus CHALCIS Fabricius.

Since some of the species of *Chalcis* from Europe and Japan are being introduced into this country, it appears best to give a table of all of the species of the genus known to occur in the United States and to include in this table the exotic species which are involved.

In the following table and descriptions of species the term "tubercle of hind coxæ" refers to a small projection on the ventral side of certain species (fig. 9). The tubercle of the hind femur is the small elevation on the inner side near base and on the lower margin of the femur (fig. 20).

In all of the figures showing the carina which separates the malar space from the face, the drawings are made facing the left.

TABLE OF SPECIES OF THE GENUS CHALCIS.

1. Hind femora on outer side black or black and yellow 2
   Hind femora on outer side red, or red and yellow, or red and black 12
2. Carina at front of malar space not branched, running direct to eye 3
   Carina at front of malar space branched or directed backward before reaching eye 5
3. Hind femora closely punctured, tooth nearest base on lower margin of hind femora triangular. (America) ..... *ovata* Say.
   Hind femora almost impunctate, especially the inner side, tooth nearest base of hind femora massive 4
4. Hind femora on outer side yellow at base and apex. (America) .. *robusta* Cresson.
   Hind femora yellow only at apex. (America) ..... *incerta* Cresson.
5. Scape in front with a yellow spot 6
   Scape in front entirely dark 7
6. Hind femora mostly yellow. (America) ..... *tegularis* Cresson.
   Hind femora mostly black. (America) ..... ♂ *coloradensis* Cresson.
7. Inner side of hind femora distinctly, closely punctured 8
   Inner side of hind femora almost entirely impunctate 11
8. Posterior tibiæ behind mostly black 9
   Posterior tibiæ behind yellow except basally 10
9. Hind femora entirely black, hind tibiæ black with a small yellow spot at apex. (America) ..... *tarsata* Dalla Torre.
   Hind femora with a yellow spot at apex; hind tibiæ with a yellow annulus near base. (Japan) ..... *fiskei*, new species.
10. Hind tibiæ at base black; a small area beneath antenna smooth; pupal skin light colored. (Japan) ..... *obscurata* Walker.
    Hind tibiæ at base yellow or reddish; no smooth area beneath each antenna; pupal skin dark brown. (Europe) ..... *flavipes* Panzer.
11. Wings hyaline; tooth of metathorax less prominent, the outline more obtuse, the front edge directed backward. (Japan) ..... *paraplesia*, new species.
    Wings dusky; tooth on metathorax more prominent, the outline more acute, the front edge almost vertical. (Europe) ..... *minuta* Linnæus.
12. Mesonotum red. (America) ..... *belfragei* Crawford.
    Mesonotum black 13
13. Face with a distinct carina between antennal fossa and eyes, originating back of anterior ocellus; antennal fossa carinate. (America) ..... *pedalis* Cresson.
    Face not so carinate 14
14. Antennal fossa very wide, separated from eyes by about length of first joint of funicle 15
    Antennal fossa narrow; separated from eyes by more than length of first joint of funicle 16

15. Small; abdomen basally red; tooth nearest base of hind femora not larger than rest; hind coxæ of female not toothed. (America)..... *columbiana* Howard.
    Large; abdomen black; tooth basad on hind femora very large; hind coxæ of female toothed. (America)..... *slossonæ* Crawford.
16. Scape in front with a yellow spot. (America)..... *coloradensis* Cresson.
    Scape in front black..... 17
17. Small, about 4^{mm}, wings milky hyaline, lateral teeth on metathorax not prominent. (Europe)..... *fonscolombei* Dufour.
    Larger, about 6^{mm}, wings dusky, lateral teeth on metathorax prominent, acute. (Japan)..... *callipus* Kirby.

CHALCIS OVATA Say.

(Figs. 8–10.)

Chalcis ovata Say, Keating's Narrat. Exped., II, app., p. 326, 1824.

This native species is separated from all the exotic species discussed in this article by the fact that the carina at the front of the

FIG. 8.—*Chalcis ovata*, female Head, showing carina at front of malar space. (Original.)

FIG. 9.—*Chalcis ovata*, female: Ventral view of hind coxa, showing tubercle. (Original.)

FIG. 10.—*Chalcis ovata*, female: Hind femur and tibia, showing markings. (Original.)

malar space runs direct to the eye; in the female the hind coxæ are armed with a small tubercle; the inner side of the hind femora is distinctly punctured, and without a tubercle on the lower margin near base; the hind tibiæ are either with or without a black annulus medially; the form with the annulus is illustrated.

CHALCIS ROBUSTA Cresson.

(Fig. 11.)

Chalcis robusta Cresson, Proc. Ent. Soc. Phila., IV, p. 101, 1865.

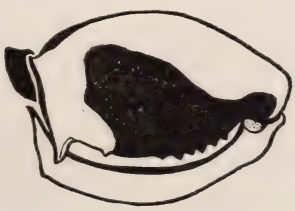

FIG. 11.—*Chalcis robusta*, female: Hind femur and tibia, showing markings. (Original.)

CHALCIS INCERTA Cresson.

(Fig. 12.)

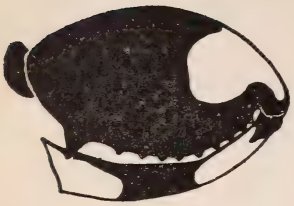

FIG. 12.—*Chalcis incerta*, female: Hind femur and tibia, showing markings. (Original.)

Chalcis incerta Cresson, Proc. Ent. Soc. Phila., IV, p. 101, 1865.

Both of the Cuban species, *Chalcis robusta* and *C. incerta*, are to be found in southern Florida. The massive basal tooth of the hind femora distinguishes them from the other species in the United States.

CHALCIS COLORADENSIS Cresson.

Chalcis coloradensis Cresson, Trans. Amer. Ent. Soc., IV, p. 60, 1872.

In the male of this species the hind femora are black, except the apex, which is yellow; the female, however, has the femora red; the hind femora have on the lower edge near base an indistinct tubercle. I am unable to distinguish *C. tachinæ* Howard from this species.

CHALCIS FISKEI, new species.

(Figs. 13–14.)

Female.—Length, about 6.5^{mm}. Black, head and thorax strongly, umbilicately punctured, with long yellowish pubescence; face below insertion of antennæ rugoso-punctate; antennal fossa extending to anterior ocellus; carina at front of malar space running backward to join the carina at the rear, making a triangularly inclosed malar space; antennæ black, pedicel short, transverse; depressed apical margin of scutellum broad, slightly emarginate medially; metathorax, back of outer end of metathoracic spiracle, with a toothlike elevation; tegulæ yellow; wings dusky; postmarginal vein about twice as long as the short stigmal; legs black; front and middle legs with the femora apically, the tibiæ at bases and apices, the tarsi, and the anterior tibiæ in front, yellow; a small yellow spot at the apex of the hind femora, and a small yellow spot at the base and one at the apex of the hind tibiæ on the outer side; the hind tarsi entirely yellow;

FIG. 13.—*Chalcis fiskei*, female: Hind femur and tibia, showing markings. (Original.)

FIG. 14.—*Chalcis fiskei*, female: Head, showing carina at front of malar space. (Original.)

hind femora on the lower margin with a triangular tooth near base, the space between this tooth and the apex of the femur occupied by about a dozen teeth, those in the middle of the series the largest and almost as large as the basal tooth, the teeth in the series decreasing in size from the middle toward both ends; hind femora distinctly punctured on the inner side; first segment of abdomen smooth, having a spot on each side with setigerous punctures; second segment at sides and on base with large setigerous punctures, the dorsal apical part of the segment with small punctures; the following segments basally smooth, the apical margins with fine punctures mixed with large setigerous punctures, sixth segment entirely covered with large punctures.

Male.—Length, about 6.5^{mm}. Similar to the female, but with more yellow on the legs, the front and middle tibiæ mostly yellow, the spots on the hind tibiæ larger and occasionally meeting, making a yellow stripe on the outer side; teeth along the lower margin of the femora smaller.

Habitat.—Japan.

Described from 12 specimens reared at the Gypsy Moth Parasite Laboratory from material received from Prof. Trevor Kincaid and Prof. S. I. Kuwana. This is a parasite of Tachinidæ.

Type.—Cat. No. 12789, U. S. National Museum.

CHALCIS OBSCURATA Walker.

(Figs. 15–16.)

Chalcis obscurata Walker, Trans. Ent. Soc. London, f. 1874, p. 399.

In this species the hind coxæ of the female have a small tubercle; the hind tibiæ are yellow except the extreme base, which is black; the face immediately below the antennal fossa is smooth and polished, especially a spot below the insertion of each antenna; the hind femora are distinctly punctured on the inner side and without a tubercle near the base. This species and the following resemble superficially the form of *C. ovata* which has the hind tibiæ without the medial black annulus but the structure of the carina at the front of the malar space readily separates them. This Japanese species is a parasite of *Porthetria dispar* and has been reared by G. Ojima, Kumamoto, and S. I. Kuwana, Tokyo.

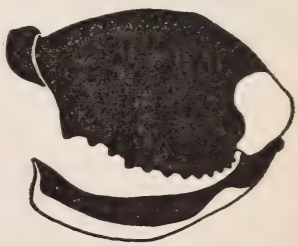

FIG. 15.—*Chalcis obscurata*, female: Hind femur and tibia, showing markings. (Original.)

FIG. 16.—*Chalcis obscurata*, female: Head, showing carina at front of malar space. (Original.)

CHALCIS FLAVIPES Panzer.

(Figs. 17–18.)

Chalcis flavipes Panzer, Fauna Insect. German, VII, p. 78, 1801.

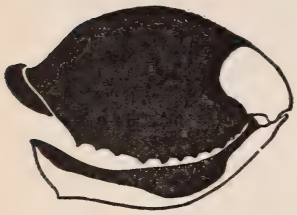

FIG. 17.—*Chalcis flavipes*, female: Hind femur and tibia, showing markings. (Original.)

This European species closely resembles the above, having the tubercle on the hind coxæ of the female, and the inner side of the hind femora punctured and without the tubercle near base, but is separated by the characters given in the table. It, also, is parasitic on *Porthetria dispar*.

FIG. 18.—*Chalcis flavipes*, female: Head, showing carina at front of malar space. (Original.)

CHALCIS MINUTA Linnæus.

(Figs. 19–21.)

Vespa minuta Linnæus, Syst. Nat., Ed. 12, I, p. 952, 1767.

In this European species the hind femora have a tubercle near base on the inner side below. The inner side of the hind femora is not distinctly punctured. In the female the hind coxæ are without

FIG. 19.—*Chalcis minuta*, female: Hind femur and tibia, showing markings. (Original.)

FIG. 20.—*Chalcis minuta*, female: Hind femur, inner side, showing tubercle near base. (Original.)

FIG. 21.—*Chalcis minuta*, female: Head, showing carina at front of malar space. (Original.)

a tubercle. This species and the following superficially resemble *C. ovata*, but are distinguished by the form of the carina at the front of the malar space, as well as by having the inner side of the hind femora impunctured and with a tubercle near base. It is a parasite of flies of the family Sarcophagidæ, which are scavengers on the dead pupæ of the gipsy moth.

CHALCIS PARAPLESIA, new species.

(Figs. 22–23.)

Female.—Length, about 5.5mm. Head and thorax coarsely, umbilicately punctured, face below insertion of antennæ rugoso-punctate; the carina at front of the malar space runs almost to eye, then obliquely backward and upward to join carina at rear; malar space shiny, weakly sculptured; depressed apical margin of scutellum deeply emarginate; metathorax at sides with a small toothlike projection; tegulæ yellow; wings hyaline; legs black, marked with yellow; all the tarsi, tips of all femora, bases and tips of front and middle tibiæ, a line on front of anterior tibiæ, and apical third of hind tibiæ and a spot near base, yellow; hind femora on inner side with small, sparse, indistinct punctures; hind femora on inner side below with a distinct tubercle near base; lower margin of hind femora with a sawlike tooth near base, followed by a series of about ten smaller teeth, these decreasing in size to apex of femora; abdomen smooth, second segment and following segments at sides with some large punctures and apically minutely punctured.

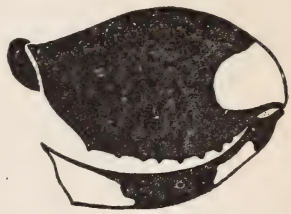

FIG. 22.—*Chalcis paraplesia*, female: Hind femur and tibia, showing markings. (Original.)

Male.—Length, 5mm. Similar to the female, but the tooth of the metathorax represented by a slightly raised carinate ridge.

FIG. 23.—*Chalcis paraplesia*, female: Head, showing carina at front of malar space. (Original.)

Habitat.—Japan.

Described from 6 specimens reared at the Gipsy Moth Parasite Laboratory from material collected by Prof. Trevor Kincaid and Prof. S. I. Kuwana. This species is parasitic in the pupæ of Sarcophagidæ.

Type.—Cat. No. 12791, U. S. National Museum.

This species is closely related to *C. minuta* Linnæus, but is distinguished by the hyaline wings and the less prominent tooth on the metathorax, which has the front edge running backward instead of almost vertical, as in *minuta*. The male of *minuta* occasionally has almost hyaline wings and is then easily separated by the strong teeth of the metathorax, the teeth being about as prominent in the male as in the female.

CHALCIS FONSCOLOMBEI Dufour.

Chalcis fonscolombei Dufour, Ann. Soc. Ent. France, x, p. 16, 1841.

This European parasite of Sarcophagidæ often has the basal half of the hind femora black; the hind tarsi are red at base and apex and black medially, the red part ornamented with a small yellow spot; the hind femora have a small tubercle on the inner side below near the base; the hind coxæ of the female are without a tubercle.

CHALCIS CALLIPUS Kirby.

Chalcis callipus Kirby, Journ. Linn. Soc. London, Zool., XVII, p. 75, 1883.

In this species the hind coxæ of the female are without a tubercle, the hind femora are very sparsely punctured on the inner side and have a tubercle near the base; the carina at the front of the malar space has, before reaching the eyes, a branch directed backward.

Of this species only one female has been seen, collected at Nishigahara, Tokyo, Japan, by Prof. S. I. Kuwana, with the record "bred from the pupa of a gipsy moth, July 12, 1908."

Family PERILAMPIDÆ Foerster.

Genus PERILAMPUS Latreille.

PERILAMPUS INIMICUS, new species.

Female.—Length, about 2^{mm}. Deep violaceous, with purple reflections, the head, metathorax, and abdomen more bluish; face not carinate; face and vertex impunctate, with scattered pubescence on the vertex; scape of antennæ blue or greenish, flagellum reddish brown, beneath more reddish; first joint of flagellum hardly longer than the pedicel; thorax umbilicately punctured, parapsidal areas along inner side, with a broad smooth area; punctures on disc of scutellum more separated, leaving a more or less distinct smooth line along center; wings hyaline; legs brown, hind legs in front purple; knees, anterior tibiæ in front, bases and tips of all tibiæ, and the tarsi entirely, light testaceous; apical margin of first abdominal segment straight.

Male.—Length, about 2^{mm}. Similar to the female; apical two-thirds of scape swollen and flattened in front, with a slight constriction between the normal base and the swollen part; legs with more light color at the bases and apices of tibiæ.

Habitat.—Japan.

Described from 6 specimens reared from cocoons of *Glyptapanteles japonicus* Ashmead at the Gipsy Moth Parasite Laboratory, from material received from Prof. Trevor Kincaid and Prof. S. I. Kuwana.

Type.—Cat. No. 12793, U. S. National Museum.

Family PTEROMALIDÆ Walker.

Subfamily PTEROMALINÆ Ashmead.

Tribe PTEROMALINI Ashmead.

Genus HYPOPTEROMALUS Ashmead.

Since the type species of this genus has a well-developed neck to the metathorax and a short but plainly visible petiole, it does not well fit in the place in Doctor Ashmead's tables in which he has put it. The following table based on antennal characters and the color of the legs separates both sexes:

TABLE OF SPECIES OF THE GENUS HYPOPTEROMALUS.

1. First joint of funicle elongate, longer than the pedicel..... 2
   First joint of funicle not elongate, scarcely longer than the pedicel. (America.) *tabacum* Fitch.
2. Femora and tibiæ light testaceous. (Japan.).....*apantelophagus*, new species.
   Hind femora green; other femora partly dark; in female the tibiæ mostly dark. (Europe.).....*pœcilopus*, new species.

HYPOPTEROMALUS APANTELOPHAGUS, new species.

Female.—Length, about 2.75mm. Bluish green, the head distinctly wider than the thorax; head, pronotum, mesonotum, and metathorax between the lateral folds, with thimblelike punctures; antennæ light brown, the scape testaceous; transverse line near rear of scutellum distinct; neck of metathorax with sculpture similar to that on basal part; lateral folds well developed; median carina wanting or very slightly indicated; wings hyaline, veins testaceous, postmarginal vein as long as the marginal, the stigmal vein distinctly shorter; coxæ blue-green, the rest of the legs yellowish testaceous, the femora and tibiæ more or less suffused with brownish; abdomen smooth, shiny, narrow, the apical segments finely lineolated.

Male.—Length, about 2mm. Similar to the female except in secondary sexual characters; head and thorax more greenish than in the female; abdomen basally with a large yellowish spot; legs less suffused with brownish than in the female.

Habitat.—Japan.

Described from 6 females and 6 males from the series reared at the Gipsy Moth Parasite Laboratory from *Glyptapanteles japonicus*, received from Prof. Trevor Kincaid and Prof. S. I. Kuwana.

Type.—Cat. No. 12973, U. S. National Museum.

HYPOPTEROMALUS PŒCILOPUS, new species.

Female.—Length, about 3mm. Green or bluish-green; head slightly wider than the thorax; head, pronotum, mesonotum, and metathorax

between the lateral folds with thimblelike punctures; antennæ dark brown, the scape basally testaceous; transverse line on scutellum distinct, the punctures back of it larger than those immediately in front of it; neck of metathorax with sculpture similar to that of basal part; median carina distinct, lateral folds well developed; wings hyaline, veins testaceous; marginal and postmarginal veins subequal in length, the stigmal vein shorter; coxæ green, front and middle femora brown with a metallic tinge, basal half of middle and hind tibiæ brown; hind femora green; knees, front tibiæ, apical half of middle and hind tibiæ, and all tarsi yellowish; abdomen smooth, shiny, the apical segments finely lineolated.

Male.—Length, about 2^{mm}. Similar to the female, except in secondary sexual characters; the scape entirely testaceous; tibiæ entirely light, slightly suffused with brownish; front and middle trochanters light, abdomen with a light spot basally.

Habitat.—Europe.

Described from 2 specimens reared at the Gipsy Moth Parasite Laboratory from *Glyptapanteles* sp.

Type.—Cat. No. 12974, U. S. National Museum.

Family EULOPHIDÆ Foerster.

Subfamily ENTEDONINÆ Ashmead.

Tribe ENTEDONINI Ashmead.

Genus PLEUROTROPIS Foerster.

The species described from Japan by Ashmead in the genus *Derostenus* have lateral carinæ on the metathorax and a distinct ring-joint to the antennæ, so that they are properly to be referred to the genus *Pleurotropis*.

The following table will separate the females of the species from Japan which have 3 joints in the funicle; *P. atamiensis* Ashmead has 4 joints in the funicle and is probably an undescribed genus.

Table of Species of the Genus Pleurotropis.

1. Median lobe of mesothorax at apex with two large foveæ....*bifoveolatus* Ashmead.
   Median lobe of mesothorax at apex without foveæ..... 2
2. Legs, including femora, testaceous.....*mitsukurii* Ashmead.
   Legs with the femora dark..... 3
3. Head above with deep thimblelike punctures..... 4
   Head above weakly sculptured.....*nawaii* Ashmead.
4. Hind tibiæ whitish.....*orientalis*, new species.
   Hind tibiæ dark colored.....*howardi*, new species.

PLEUROTROPIS ORIENTALIS, new species.

Female.—Length, about 1.5mm. Bronzy black, with green or purple reflections, the vertex and base of abdomen more greenish, the metathorax distinctly green; vertex with coarse thimblelike punctures, the frontal declivity above transverse groove smooth, below furrow with finer punctures, those below the insertion of the antennæ still finer; antennæ brown; mesonotum reticulate, parapsidal furrows not very apparent; scutellum reticulate all over, basally the lines more regular and longitudinal; metathorax smooth, median and lateral carinæ distinct; femora green, tibiæ testaceous, tarsi more whitish; first segment of abdomen medially at apex and following segments finely punctured.

Male.—Unknown.

Habitat.—Japan.

Described from 5 specimens reared from *Glyptapanteles japonicus* at the Gipsy Moth Parasite Laboratory, from material received from Prof. Trevor Kincaid and Prof. S. I. Kuwana.

Type.—Cat. No. 12975, U. S. National Museum.

PLEUROTROPIS HOWARDI, new species.

Female.—Length, about 2mm. Green, with bluish reflections, the sides of the scutellum, the apical part of the parapsidal areas, and the pleuræ purplish-black; face below the transverse furrow bluish, with fine thimblelike punctures down to the insertion of antennæ, below this still more finely and weakly punctured; above the furrow with coarse thimblelike punctures; antennæ green; pubescence of eyes distinct; mesothorax coarsely reticulate, the parapsidal furrows not very distinct anteriorly, posteriorly formed by triangular depressed areas which resemble scars, each with a single setigerous puncture; median lobe of mesonotum strongly emarginate at apex; scutellum at sides longitudinally striate, the apical portion reticulate, leaving the median basal area smooth; metathorax smooth, medially with two carinæ close together, lateral carinæ distinct; first segment of abdomen basally smooth, green, beyond this the abdomen purplish-black and finely punctured; legs green, the tarsi white, apically brown.

Male.—Unknown.

Habitat.—Japan.

Described from 8 specimens reared from cocoons of *Glyptapanteles japonicus* at the Gipsy Moth Parasite Laboratory, from material received from Prof. Trevor Kincaid and Prof. S. I. Kuwana.

Type.—Cat. No. 12976, U. S. National Museum.

Named in honor of Dr. L. O. Howard, under whose direction the parasite work is conducted.

Subfamily EULOPHINÆ Howard.

Tribe EULOPHINI Ashmead.

Genus DIMMOCKIA Ashmead.

DIMMOCKIA SECUNDUS, new species.

Female.—Length, about 2^{mm}. Bright green, the face and occiput covered with very fine, close striæ; antennæ brownish testaceous, the scape lighter colored; ring-joint distinct, pedicel shorter than first joint of funicle, about as long as joint 2; joints 2–4 subequal, only slightly longer than wide; club showing only 2 joints; mesonotum and metathorax between the lateral folds with fine thimblelike punctures, those of the scutellum finer than on the middle lobe of the mesonotum, those of the axillæ still finer and becoming in part fine striæ; scutellum with a median longitudinal line of punctures which are finer than the rest; median and lateral carinæ of metathorax very distinct; mesepisternum with thimblelike punctures; mesepimeron below finely reticulate, the upper part smooth; metapleuræ and metathorax laterad of lateral carinæ rugose; legs light yellow, the hind coxæ at base above with a small green spot; abdomen green, the apical margins of abdominal segments brownish; first and second segments smooth, the others with very fine lineolations.

Male.—Unknown.

Habitat.—Japan.

Described from 5 female specimens reared at the Gipsy Moth Parasite Laboratory from *Glyptapanteles japonicus*, from material received from Prof. Trevor Kincaid and Prof. S. I. Kuwana.

Type.—Cat. No. 12977, U. S. National Museum.

In this genus the funicle is 4-jointed and the club shows only 2 joints, so that the antennæ show 9 joints instead of 10 as given by Doctor Ashmead in his Classification of Chalcidoidea.

O

TECHNICAL SERIES, NO. 19, PART III.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

III. INVESTIGATIONS INTO THE HABITS OF CERTAIN SARCOPHAGIDÆ.

By T. L. PATTERSON,

Assistant in Biology, Sheffield Scientific School, Yale University,

WITH AN INTRODUCTION

By W. F. FISKE,

In Charge of Gipsy Moth Parasite Laboratory, Bureau of Entomology.

ISSUED MARCH 22, 1911.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1911.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, H. L. Viereck, C. W. Collins, R. Wooldridge, Jno. D. Tothill, C. W. Stockwell, H. E. Smith, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants.*

CONTENTS.

	Page.
Introduction	25
General conditions	27
Collections of gipsy-moth pupæ for maggots of Sarcophagidæ	27
Experiments with adult Sarcophagidæ	29
Experiments with first-stage maggots on living and dead material	30
Relation of decomposition to oviposition	30
Conclusion	31

U. S. D. A., B. E. Tech. Ser. 19, Pt. III, Issued March 22, 1911.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

III. Investigations into the Habits of Certain Sarcophagidæ.

By T. L. Patterson,
Assistant in Biology, Sheffield Scientific School, Yale University.

INTRODUCTION.[1]

That there are among the Sarcophagidæ a number of species which, to all intents and purposes, are primary parasites of grasshoppers is a fact concerning which there is no ground left for argument. Whether the young larvæ of these flies bear a relation to the living host which is in any way comparable to the extraordinary intimacy which characterizes the relations between the tachinid parasites and their hosts is beside the present question. They assuredly do gain access to the living body of their host, and after a time destroy it, and by so doing qualify themselves to be considered among the insect parasites.

There are numerous species of the Sarcophagidæ which have been reared in association with the gipsy moth (*Porthetria dispar* L.). Each year after the caterpillars have pupated and when the moths are beginning to emerge, interested persons have found pupæ with the shell apparently unbroken, the contents in a state of decomposition, and an active sarcophagid larva luxuriating in the surroundings thus provided. The condition of the pupa containing the sarcophagid is always different from that of a pupa containing a tachinid maggot, but the distinction is not instantly apparent nor easily described. To the ordinary observer the pupa containing the sarcophagid answers perfectly to the description of a pupa destroyed by a tachinid, and each year it has been necessary to explain anew the difference between parasite and scavenger. That sarcophagid maggots found under these conditions are always scavengers and never parasites has never seriously been questioned.

It must be admitted, however, that in thus rather summarily consigning the whole group of sarcophagids to the rôle of scavengers, in so far as their relations to the gipsy moth were concerned, there has been an undercurrent of uneasiness lest among them should eventu-

[1] Introduction by W. F. Fiske, in charge of Gipsy Moth Parasite Laboratory, Bureau of Entomology, Melrose Highlands, Mass.

ally be found some which created rather than took advantage of the conditions under which they were encountered. It required hardly any stretching of the imagination to conceive of sarcophagid maggots deposited upon living pupæ, effecting an entrance, and eventually bringing about the death and decomposition of the host. From time to time tentative attempts to acquire more definite information were made, but without positive results one way or the other. Large numbers of gipsy-moth pupæ, apparently living, were collected in the open and upon one or two occasions sarcophagid maggots were subsequently found, but there were always very satisfactory explanations for their presence other than that they were parasitic, and it was increasingly evident that if such experiments were to be decisive, they would have to be conducted with exceedingly great care. Several attempts were also made to keep the adult sarcophagids reared from gipsy-moth pupæ imported from Europe or Japan until they reached their full sexual development and were ready to deposit their brood, but there were a good many things to learn about the best way of conducting an experiment of this sort and none of them was successfully concluded.

In the summer of 1910 the question of *Sarcophaga* in its relations to the gipsy moth was rather suddenly reopened as the immediate result of a study in parasitism conducted by Mr. P. H. Timberlake, of this laboratory, upon the "pine tussock moth" which was causing some injury to pine in northern Wisconsin. The results of his studies, which will be published in another part of this bulletin, were such as strongly to indicate the parasitic character of certain sarcophagids and to suggest that they were, in effect, of rather considerable importance in the control of this moth.

This, when taken in connection with the fact that a vastly larger number of sarcophagids were continually being received in shipments of gipsy-moth pupæ from Europe and Japan than would be secured from an equal number of similar pupæ collected in America, was a circumstance which could no longer be overlooked. The evidence was such as materially to support a contention that among the European sarcophagids occurred species which were primarily enemies of the gipsy moth. If, as did not seem so very improbable, there existed in Europe such an important group of dipterous parasites of gipsy-moth pupæ, no time should be lost in attempting to secure their introduction into America.

Most unfortunately it is impossible in this case, as in a great many others, to conduct the necessary investigations to the best advantage. Independent European entomologists can not, of course, conduct elaborate investigations along lines wholly outside of their own affairs, and the establishment of a European branch of the Gipsy Moth Parasite Laboratory has never been considered as practicable.

As usual we were forced to do what could be done with such opportunities as were offered. It was decided to institute at once a new series of studies upon the relations of the American sarcophagids to the gipsy moth, and to conduct them so carefully that if they did not produce positive results they would at least possess negative value.

Fortunately the services of Mr. Patterson were available at that time, and the affairs of the laboratory were in such condition as to permit him to give the work his undivided attention. For the first time it was possible to conduct the experiments, which he will describe himself, with the adequate attention to detail which is absolutely necessary if the results are to be considered as decisive. His results seem to justify the retention of the ideas previously held. in so far as they can be justified by a study of American conditions. It is sincerely to be hoped that in the very near future similar investigations may be conducted in Europe, since the only other additional studies which seem worth while in America will be of the sarcophagids in relation to other lepidopterous hosts, and the findings, whatever their character, would not be directly applicable to the problem of gipsy-moth parasite introduction.

GENERAL CONDITIONS.

Since the establishment of the Gipsy Moth Parasite Laboratory in 1905 considerable interest has been excited each year from the number of sarcophagids reared in connection with gipsy-moth pupæ, and even more from the larger percentage of sarcophagids received from gipsy-moth pupæ imported annually from Europe and Japan. It would seem probable from the above that certain species of sarcophagids had always been parasitic, or else that they had within recent years developed the parasitic habit, which is the more likely; hence, instead of having to depend wholly upon dead material as a host they had joined the ranks of certain of the Tachinidæ in waging war against one of the most injurious insect pests that has ever invaded New England, the gipsy moth. During the last few years certain tentative experiments have been made at the laboratory, but all this work, while it proved rather interesting, was not convincing, and gave neither positive nor negative results. In the summer of 1910 conditions again became favorable for further investigations into the habits of native Sarcophagidæ and the writer attempted to determine, by the series of experiments which follow, whether any of these flies are parasitic in habit, or whether they are scavengers on the gipsy moth.

COLLECTIONS OF GIPSY-MOTH PUPÆ FOR MAGGOTS OF SARCOPHAGIDÆ.

Collections were made of gipsy-moth pupæ from localities in towns within a radius of 10 miles of the laboratory. The smallest collection contained 225 and the largest 790 pupæ, each of which was care-

fully examined and placed into one of two separate lots, namely, the live and active, or the dead, abnormal, and inactive. A few small collections were also made of active prepupal larvæ which were kept separate from the other lots. All of these lots were placed in small pasteboard boxes about 8 by 5 by 4 inches, with tight covers, and were examined almost daily for either maggots or puparia of Sarcophagidæ, or parasites, and the moths as they issued from the pupæ were removed and killed. The small number of pupæ from which no moths issued was dissected for parasites at the close of the experiments. Three thousand two hundred and fifty-seven pupæ and prepupal larvæ were collected for the experiments, 300 of which were active prepupal larvæ, 591 were dead and inactive pupæ, and the remaining 2,366 were active pupæ. No sarcophagids were reared from the lots of active pupæ and active prepupal larvæ, but 2 puparia of the tachinid parasite *Compsilura concinnata* Meig. developed from one of the lots of the active pupæ and 14 were secured from the prepupal larvæ. This parasite of the gipsy moth and brown-tail moth was introduced from Europe and liberated in eastern Massachusetts. It has become so well established here, according to the best authorities and records, that it is now distributed over more than 200 square miles of the infested territory.

From the dead and inactive pupæ, as might have been expected, sarcophagids were obtained, as well as other species which work as scavengers or parasites. This material yielded 4 third-stage maggots and 1 second-stage (dead) maggot of the Sarcophagidæ; 4 puparia and 1 third-stage maggot (dead) of *Compsilura concinnata;* 1 *Exorista blanda* O. S.; 2 third-stage maggots and 1 second-stage tachinid maggot of an unknown species; 14 *Monodontomerus* adults and 2 pupæ of the same; 8 pupæ of *Gaurax anchora* Loew (?); and 1 adult and 4 pupæ of *Theronia* and 5 *Dibrachys* (dead) in 1 gipsy moth pupa. A special lot of 5 prepupal larvæ was collected, and on dissection 2 proved to be alive, 2 dead, and 1 had pupated while being brought in from the field. In one of the live prepupals a second-stage maggot of *Compsilura concinnata* was obtained, while the other was not parasitized. One of the dead prepupals produced 3 third-stage maggots of the Sarcophagidæ, while the other, as well as the freshly formed pupa, contained no parasites.

The above experiments not only uphold, but seem rather to strengthen the old belief that the sarcophagids are simply scavengers. Another point of interest in this line of investigation is that there are sometimes found in a single pupa more than one parasite, which often belong not only to entirely distinct and separate genera, but even to entirely distinct and separate families. This point was well illustrated in making one of the collections, when the posterior end of a

dead gipsy-moth pupa was accidentally broken off in removing it from the tree, thus disclosing within its almost empty case 2 third-stage maggots, one *Compsilura concinnata* and the other a sarcophagid. This may be very satisfactorily explained by the fact that this pupa, when in the caterpillar stage, was first parasitized by *Compsilura concinnata*, and after reaching the pupal stage the maggot within became large enough to kill the pupa. The decomposition which resulted furnished a favorable place for the oviposition of a female sarcophagid. In various other cases, when it appeared as an almost absolute certainty that maggots of the Sarcophagidæ came from living material, their presence could be accounted for in some such way as the above. The following experiments with the native sarcophagids will also go to strengthen and substantiate the above theory.

EXPERMENTS WITH ADULT SARCOPHAGIDÆ.

Collections were made of these flies for reproduction experiments from different localities in the infested area. Each collection was kept separate in cylindrical wire screen (one-twelfth-inch mesh) cages, 10 inches in height by about 4 inches in diameter. The top consisted of a circular piece of wood, to which was tacked the wire screen, while the lower edge of the screen fitted into a groove in the wooden base. This arrangement allowed the quick removal of the base and furnished easy access to the cage. A sprig of leaves, with the stem wrapped with cotton batting, was inserted in a tube of water attached to the inside of each cage, and this was sprayed with a solution of sugar and water twice daily, which furnished food for the flies. At first only active prepupal larvæ of the gipsy moth were placed in these cages. They pupated in a day or two and were allowed to remain there for several days, where the flies could have free access to them, before they were transferred to jelly glasses, which were covered with cheesecloth. These were kept under observation for sarcophagid maggots until the moths emerged or the pupæ died, in which cases they were always dissected. All these experiments gave negative results, showing almost conclusively that these flies did not oviposit on living pupæ. The writer then added some badly decomposed caterpillars to the living ones in the cages and observed in a short time that the female flies deposited tiny maggots on the dead material, but not on the living, although frequently they crawled over the live pupæ until these wriggled, which seemed to frighten the flies away. The living material from these experiments was also placed in jelly glasses, but all finally gave negative results. All dead material was now placed in the cages and first-stage maggots were obtained quite plentifully and appeared to be perfectly healthy.

EXPERIMENTS WITH FIRST-STAGE MAGGOTS ON LIVING AND DEAD MATERIAL.

Some of these maggots were placed on mature active pupæ, but in every instance they showed little, if any, desire to bore through the pupal cases. This would probably be an impossibility, as the exterior of the pupæ is tough and hard, but the maggots did not enter even the soft prepupal larvæ. In both cases the pupæ and prepupal larvæ were greatly disturbed and irritated when maggots were crawling on them, and they wriggled violently, dislodging the maggots. If they were placed on a soft, freshly formed pupa the maggots at once would make frantic attempts to bite into it, but without success; although, in one instance, when the membrane which holds the wing cover to the body of the pupa became ruptured, the maggot took advantage of this opportunity of concealment and crawled beneath, and although the maggot was still on the external surface of the pupa it caused such an irritation by its movements that a dark secretion oozed out, coming either from the pupa, maggot, or both, and in the course of a few hours the wing cover became sealed to the body of the pupa, so that only the anal stigmata of the maggot were left exposed. After the lapse of about 12 hours the pupa was found to be dead, and in 18 or 20 hours the maggot disappeared into the body of the pupa. A dissection was made the following day. The maggot was found dead midway in the body of the pupa. This would seem to indicate that the environment which the maggot found within the pupa was not favorable for its development.

To further illustrate the above idea the writer took active pupæ, making a puncture about midway in the body of each, and allowed a live maggot to crawl in, but in all cases the maggots died, showing that they can not live under such circumstances. However, a few came out of the pupæ and died on the outside. Similar experiments were made on dead material with entirely different results. In most cases the maggots went in without experiencing any difficulty and usually survived, which showed that they were in a natural environment.

RELATION OF DECOMPOSITION TO OVIPOSITION.

It was observed that the flies would not oviposit on freshly killed material in the cages, even though the females had been ovipositing previously on older decomposing caterpillars. This would seem to refute the parasitic theory and would tend to show that the material must reach a certain stage of decomposition before the females would oviposit. Selecting the only cage where females were ovipositing the writer removed all the old material and replaced it with a single freshly killed caterpillar. The flies at once ceased to oviposit,

although they would crawl about over it. Two days later the writer observed one of the female flies in this cage spending the most of her time crawling about over this caterpillar. A little later she began to make a buzzing noise with her wings and was feeling here and there with her proboscis over the body of the decomposing caterpillar. Proceeding to the anterior portion of the caterpillar a few segments back of the head she succeeded in puncturing the decaying skin with her proboscis, and then moving along far enough so that the end of her ovipositor was directly over this puncture she slowly deposited a maggot which immediately, true to its instincts, worked its way through this puncture into the body of the caterpillar. Several maggots were deposited by this fly, and later a second female was observed to oviposit on the caterpillar in the same incision. This not only indicates that a certain stage of decomposition must be reached, but that the skin of the caterpillar must be either broken, or in such a condition that the female fly can puncture it with her proboscis before she will oviposit, thus allowing an opportunity for the maggots to crawl into the dead host. There were a few living pupæ in this cage, and although the females not infrequently crawled about over them, they did not attempt oviposition. This was the case with a freshly killed caterpillar which was placed beside a dead specimen upon which flies were ovipositing, but when decomposition reached the proper stage, the flies began to oviposit freely. It must be stated here that the true source of the flies in the cage with which this last experiment was tried was unknown, and that they were selected only for the reason that they happened to be the only flies available that were ovipositing. They were secured from a jar containing dead European *Calosoma* beetles which had been exposed for several weeks to the attack of various species of sarcophagids. It is possible that these flies might have been imported from Europe, but this is extremely doubtful.

CONCLUSION.

These experiments indicate very conclusively that the sarcophagids in New England do not destroy living gipsy-moth larvæ or pupæ in the field. From a collection of 2,666 specimens not a single sarcophagid was reared.

In cages the flies would not oviposit on healthy or recently killed caterpillars or pupæ, but did so freely after they became slightly decomposed.

First-stage maggots, when placed artificially within living pupæ, failed to develop in every instance, showing that the conditions were not favorable for their growth.

When living and decomposing larvæ or pupæ were placed side by side in a cage, the flies selected the latter on which to oviposit, and normal larvæ developed.

In conclusion it must be understood that the writer has not attempted to work with any one species of the Sarcophagidæ, nor to separate them into species, but, on the other hand, he has worked with them only as a family, taking for granted that if any of these flies are ever parasitic on the gipsy moth, they would naturally be found in the infested localities. Although all the experiments have given negative results, yet they are nevertheless of economic importance, because in Europe and Japan, where sarcophagids are more commonly associated with the gipsy moth than in this country, it is possible that there may be several species that have the parasitic habit. If so, foreign investigations should be hastened, for if introduced into America these parasitic sarcophagids would be an important addition to the natural enemies of the gipsy moth.

○

TECHNICAL SERIES, NO. 19, PART IV.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

IV. THE CHALCIDOID GENUS PERILAMPUS AND ITS RELATIONS TO THE PROBLEM OF PARASITE INTRODUCTION.

By HARRY S. SMITH,

Expert.

ISSUED APRIL 22, 1912.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of Southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *in charge of library.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, Harry S. Smith,[1] P. H. Timberlake,[2] C. W. Collins, H. E. Smith, F. H. Mosher, J. N. Summers, Chas. W. Minott, C. W. Stockwell, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants.*

---

[1] Transferred to Cereal and Forage Insect Investigations.
[2] Transferred to Citrus Fruit Insect Investigations.

CONTENTS

	Page.
Introductory	33
Biology of *Perilampus hyalinus* Say	34
Oviposition	37
Reproductive capacity	39
Description of planidium	39
Habits of planidium	41
Life as a parasite of *Varichæta*	42
As a parasite of *Limnerium validum* Cresson	43
As a parasite of summer-issuing Hymenoptera	44
As a parasite of other hosts	45
Later larval stages	45
Pupation	47
Food habits of the adult	48
Longevity and oögenesis	49
Length of life cycle and influence of temperature	49
Effect of parasitism upon host	51
Percentage of parasitism	52
Superparasitism	53
Perilampus versus *Perilampus*	53
Perilampus versus *Dibrachys*	55
Perilampus, "species A"	55
Development of *Orasema*	57
Planidium of *Orasema viridis* Ashmead	59
Relationship of Eucharidæ and Perilampidæ	59
Rhipiphorus and other coleopterous parasites	60
Host relations of the genus *Perilampus*	61
Rearing records of *Perilampus hyalinus* at the laboratory	61
Other American rearing records of *Perilampus*	62
European rearing records of *Perilampus*	64
European species of *Perilampus* reared at the laboratory	65
Résumé of host relations of the genus	66
The economic aspects	67

ILLUSTRATIONS.

Page.

FIG. 24. *Perilampus hyalinus:* Planidium, ventral view 40
25. *Perilampus hyalinus:* Planidium, dorsal view 40
26. Pupa of *Varichæta aldrichi*, parasitized by *Perilampus hyalinus;* pupa of same unparasitized; planidium of *Perilampus hyalinus*, before and after feeding 46
27. *Perilampus hyalinus:* Mature larva 47
28. *Perilampus hyalinus:* Fresh pupa 48
29. *Perilampus hyalinus:* Pupa just previous to eclosion 48
30. *Perilampus*, "species A": Planidium, ventral view 56
31. *Perilampus*, "species A": Planidium, dorsal view 56

U. S. D. A., B. E. Tech. Ser. 19, Pt. IV. Issued April 22, 1912.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

IV. The Chalcidoid Genus Perilampus and its Relations to the Problem of Parasite Introduction.[1]

By HARRY S. SMITH, *Expert.*

INTRODUCTORY.

Practical utilization of parasites in the control of noxious insects is becoming a more and more important means of warfare in economic entomology. For that reason accurate and detailed knowledge of the life history of the various parasitic groups is indispensable to an intelligent handling of the intricate problems which continually present themselves in work of this kind. It does not suffice merely to know that an insect is a primary parasite or a hyperparasite. Familiarity with the intimate details in its life and habits is of the utmost importance in order that it may be brought to its maximum of efficiency with the least possible delay; or, should it prove to be a hyperparasite, that an injurious insect may not thus be released unwittingly and irreparable damage be done. The great desirability of bringing this phase of economic entomology to a position of prominence has been the prime motive for a solution of some of the most perplexing problems which have confronted the student of insect parasitism; for example, the work of Marchal and Silvestri on the development of the hymenopterous, and of Townsend and Nielsen on the dipterous parasites. These men are economic workers and their discoveries of the extraordinary phenomenon of polyembryony or germinogony in the parasitic Hymenoptera and of the unusual habits of oviposition and larviposition in the tachinid parasites were made in connection with a study of the practical utility of these insects in the control of injurious species. Such investigations are interesting not only from the purely scientific standpoint, but are more than justifiable from that of applied entomology.

The few forms studied by these entomologists are among the most common species, which goes to show how limited the present knowledge of the biology of insect parasites really is. A fascinating field of study is open to those in a position to undertake research of this

[1] The writer is indebted to Mr. W. F. Fiske for valuable suggestions and criticisms throughout the course of his work on *Perilampus*.

kind, the requirements for investigating these most interesting phenomena, where the more common species are concerned, being, as stated by Dr. L. O. Howard, "simply good laboratory facilities and a skilled technique, together with trained powers of observation." These, as he points out, are to be found in many institutions and with many individuals in this country. The element of a chance discovery sometimes enters into consideration, however, even when a common insect is made the subject of study. Quite as often as not the discovery of the thread which will later lead to an unraveling of the complete life history is nothing more nor less than an accident, the clue being stumbled upon in a place and at a time altogether unlooked for. The investigations of the life history of *Perilampus hyalinus* Say received their initial impetus from just such an accidental discovery.

BIOLOGY OF PERILAMPUS HYALINUS SAY.

When time and opportunity have permitted, the parasites of certain among the native leaf-feeding caterpillars have been studied at the Gipsy Moth Laboratory in order to determine the part which parasitism plays in their natural control, and in an endeavor to arrive at a better understanding of the varied phases of the problem. Among others, the fall webworm (*Hyphantria textor* Harris) was selected as a promising subject, and, coming as it does at a season just after the summer's work on gipsy moth parasite importation and colonization is over, it has been possible to devote a larger share of our attention to it than to other even more interesting species which complete their transformations earlier in the season. Upon several occasions the young caterpillars have been brought in from the field, placed in insect-proof rooms and cages, and fed. In due time primary parasites, usually tachinids, species of the ichneumonid genus *Limnerium*, and occasionally *Apanteles*, emerged from these caterpillars, and the cocoons and puparia were removed to tightly stoppered vials and placed aside for the emergence of the adults. Later examination revealed the fact that adults of the species which formed the puparia or cocoons could not always be expected to emerge, for usually a certain percentage produced adults of *Perilampus* instead. How the adult female *Perilampus* obtained access to these puparia and cocoons in order to oviposit in them was a mystery inasmuch as especial pains had been taken to make the rooms and cages containing the caterpillars parasite-proof. But for a fortunate discovery during the spring of 1909 the true significance of these perplexing observations would doubtless have remained a mystery for some time to come.

While engaged in experimentation for developing a better technique in the preparation of hymenopterous larvæ for microscopical study, in which work the larvæ of the common *Limnerium validum* Cresson, an important parasite of the fall webworm, were used as subjects, a

strange little creature was discovered which was obviously the larva of an insect, but which differed very materially from any familiar form. It was impossible, from external characters, to assign it to any particular order with assurance, and consultation with several of the ablest entomologists of the country failed to throw any light upon the subject.

It was less than three-tenths of a millimeter in length, and therefore almost invisible to the unaided eye, oblong-ovate in shape and dark brown in color. Examination under the microscope showed it to be a highly organized being with well-defined mouth parts, strong, curved mandibles, conspicuous tracheal system, etc. The 13 segments were well differentiated, the first forming a distinct head, which was armed with several recurved hooks. The dorsal segments consisted of a series of heavy, chitinous, and overlapping plates, which nearly encircled the body. Most of these were furnished with one or two pairs of bristles. Ventrally the larva was furnished with several backward-projecting spines, which were evidently ambulatorial in function. An attempt to rear the adult from this larva was unsuccessful.

Among the minor projects under way at the laboratory at this time was a study of the biology of *Dimmockia incongrua* Ashmead, a rather common and important native chalcidoid parasite of tachinids. As a host for the rearing experiments with *Dimmockia* one of the most common native dipterous parasites, *Varichæta aldrichi* Townsend, also an important enemy of the fall webworm, was utilized.

In the course of an examination of the pupæ of this tachinid for the eggs and young larvæ of *Dimmockia* a second specimen of the remarkable creature referred to above, or to be more accurate one similar to it, was encountered. This second specimen, instead of being firmly attached to its host by its anterior end as was the former, was quite free and crawled about over the body of the tachinid pupa in a startlingly businesslike manner. This observation very naturally led to a further search through the abundant material at hand, and the presence of the strange parasite, for such it was now suspected of being, was found to be of not at all rare occurrence. An excellent opportunity was at once afforded for ascertaining the identity of the parasite and the subsequent rearings through the different stages were made with a great deal of eagerness. Immediately upon the completion of the first ecdysis it was seen that the larva resembled rather closely what was known to be the mature larva of *Perilampus*, and the further development of the specimens under observation confirmed that suspicion. The first-stage larva is of a very unusual type, which, with a single exception so far as known, has not been observed before. This exception is the larva of *Orasema viridis* Ashmead, described and figured by Dr. William Morton Wheeler.[1]

[1] Bulletin of the American Museum of Natural History, vol. 23, Art. I, 1907.

A comparison of the peculiar first-stage *Perilampus* larva with the *Orasema* material in Dr. Wheeler's possession indicated that while the two were very different in anatomical detail, they were of the same general character and constitute a type which, Dr. Wheeler has suggested, may be designated by the term "planidium."[1]

The establishment of the identity of the planidium did not assist materially in clearing up the mysterious circumstance attending the rearing of the *Perilampus* from the *Limnerium*, *Varichæta*, and *Apanteles* parasitic on the fall webworm, and with the end in view of determining if possible the manner in which *Perilampus* gained access to its host, several thousand young caterpillars of *Hyphantria* were collected during the following fall, placed in rearing trays, and reared to maturity. At frequent intervals a large series of these caterpillars was killed and preserved in order that abundant material might be had for study during the winter.

Apanteles hyphantriæ Riley was found to be a fairly common parasite of the younger caterpillars, and *Varichæta aldrichi* and *Limnerium validum* of the older ones, as during the preceding summer. Examination of the puparia and cocoons of the parasites disclosed the fact that the planidia of *Perilampus* were even more common than they were during the preceding year, and as large quantities of material in all stages had been preserved an excellent opportunity was afforded for working out the life history of this remarkable parasite.

As has been mentioned on a preceding page, *Perilampus* was frequently reared from puparia and cocoons formed in tight rooms or breeding cages into which it was thought impossible for an adult parasite to gain entrance. Consequently in seeking an explanation of the presence of the planidia of *Perilampus* in the puparia and cocoons of these primary parasites of *Hyphantria*, it seemed most plausible that the female oviposited in or on the caterpillar containing the parasite which was later to become the host of the young *Perilampus*. Acting upon this hypothesis, maggots of the tachinid which had emerged from the caterpillar were examined and found to contain the planidia internally. The planidium, by reason of its dark color, was easily visible through the semitransparent integument of the maggot, and even after the latter had ceased activity and had formed its puparium the *Perilampus* larva could be seen through the shell until it had changed color and had become quite opaque. Dissection of the fully developed caterpillars revealed the fact that the tachinid maggots *while still within the caterpillar* contained these planidia, and going back still further, to the younger caterpillars, the planidia were found to be present here irrespective of whether the caterpillar was infested by a primary parasite or not.

[1] From the Greek πλανητης, a wanderer, and ιδιον, diminutive.

Examination of a considerable number of the *Hyphantria* caterpillars showed that the planidium could be found in almost any portion of the caterpillar's anatomy, although they generally "floated about" freely in the body cavity. Occasionally specimens attached to the larval organs, such as the alimentary canal or silk glands, were encountered. Further study of still younger caterpillars revealed the most interesting and significant feature of the whole life cycle, namely, the presence of the planidia *upon the exterior* of the caterpillars. These were apparently about to make their way through the integument to the interior in a search for suitable hosts upon which to complete their development. The less heavily chitinized portions of the caterpillar's skin, that is, the portion between the different segments, offered the most vulnerable point of attack and almost invariably this was the place selected by the parasite for making an entrance. Individuals which had not yet started an opening were found quite as frequently upon the middle of the segments as between them. Just how these planidia came to be located upon the skin of the caterpillars and how, when, and where the adult female *Perilampus* places her eggs, we have been unable to ascertain up to the present time, and any statement in regard to this portion of the life cycle must take the form of mere conjecture.

OVIPOSITION.

There have been made, so far as published records go, at any rate, no observations upon the oviposition of members of the genus *Perilampus*. It is known, however, that oviposition does not occur in the normal way, or in the manner we are accustomed to regard as the normal method of oviposition among the parasitic Hymenoptera, and for this reason speculations on what may actually occur are rather interesting.

In the first place it is obvious from the facts recorded in the preceding pages that *Perilampus* does not oviposit directly in or upon its host. In the second place, it does not oviposit within the caterpillar of which its host is a primary parasite, which is equally obvious from observations already made. That it places its eggs *upon* the young caterpillar is improbable, the adult *Perilampus* being too slow and clumsy to be capable of accomplishing this act with any degree of certainty.

There are two plausible methods which *Perilampus* might adopt for the deposition of its eggs, and the writer is strongly inclined to the view that one of these methods is in part at least correct. As in the case of some of the parasitic beetles, it may deposit its eggs upon flower heads or upon leaves of plants not in the immediate vicinity of the caterpillar colony, the planidia hatching from these

eggs being conveyed to the caterpillars by means of some intermediate carrier. In the Coleoptera cited above the carrier is frequently a parasitic bee upon which, by means of their claws, the triungulins attach themselves and are conveyed to the nest of their host. With *Perilampus*, should this method prove to be the one which really takes place, the intermediate carrier might be any of the primary parasites which attack *Hyphantria*; that is, the hymenopterous parasites *Limnerium* or *Apanteles*, or the tachinid *Varichæta*. The planidium seems more or less fitted for this sort of a life and is apparently analogous to the triungulin of the coleopterous parasites. The chitinous plates with which it is armored are especially serviceable in preventing injury of various kinds, and the mandibles and hooks and spines would serve it very well as a means of clinging to its conveyer.

Varichæta as a conveyer of the planidia would expose the young *Perilampus* to one more vicissitude, as it does not oviposit upon the caterpillars, but deposits young maggots upon the leaves of the food plant of its host. These maggots, should they by good fortune happen to have been placed upon a leaf which is later crawled over by a caterpillar, fasten themselves upon their host when the opportunity offers. *Perilampus* then would twice be subjected to the same conditions as these maggots, and their success in finding a host would depend entirely upon whether or not caterpillars came within their reach.

The other method, which seems much more plausible, is that of oviposition upon the food plant *in the vicinity of a colony* of the caterpillars. This would do away with the necessity of an intermediate carrier, but would expose the delicate eggs to great danger unless they hatched immediately after deposition.

Both theories have their faults and it may easily be that neither is correct. They are offered simply as suggestions to anyone who has the opportunity to make observations upon this parasite, in the hope that they will be of assistance in completing the knowledge of this strange life cycle. The former hypothesis has the advantage of a parallel in the parasitic Coleoptera, while something similar to the latter is known to occur in certain of the tachinid parasites (notably *Varichæta*, as mentioned above) which deposit young maggots upon the leaves, the maggots attaching themselves to the caterpillar as it crawls over the leaf upon which they are located.

While the eggs of *Perilampus* have not been observed after deposition, those contained in the ovarian tubes, in one case apparently mature, have been examined. They are of the usual elongate-oval shape, not stalked, and whitish in color.

REPRODUCTIVE CAPACITY.

It is a well-known fact that insects which are subject to very high mortality in their younger stages must have a high potential rate of reproduction in order to offset this loss and still prevent the species from becoming extinct; and conversely, we may say that insects laying a great number of eggs must of necessity experience a very high death rate or else they would in time increase beyond all bounds. We have found by the dissection of adult female *Perilampus* that the eggs are very numerous, the abdomen containing as high as 250 fully developed eggs at one time. It is therefore apparent that in some stage or stages before maturity many of the young die. As *Perilampus* is eminently well fitted to withstand the vicissitudes encountered in its later existence, the logical place to find this high death rate is during the planidium stage, while the tiny larva is wandering about either within or outside the caterpillar in search of its host. That this wandering habit of the younger, pre-eruciform stages of parasitic larvæ is accompanied by great mortality is well exemplified in the case of the Strepsiptera. Newport, in his "History and General Anatomy of Meloë and Its Affinities,"[1] records the production of more than 7,000 triungulins by a single female of the genus *Stylops*. *Perilampus* is apparently not only subject to a considerable mortality by reason of its wandering habit, but large numbers meet their death through a failure to find a proper host within the caterpillar and through the operations of superparasitism after they do find their host.

Whatever be the real method by which the planidium becomes affixed to the caterpillar, the life history from this point on has been worked out by actual observation in the laboratory, with an abundance of material for study.

DESCRIPTION OF PLANIDIUM OF PERILAMPUS HYALINUS.

(Figs. 24, 25.)

Length about 0.3 mm., depending on the amount of distension; diameter at widest place about 0.06 mm. Shape obovate; composed of 13 distinct segments or rings which are dark brown and heavily chitinized, and which "telescope" into each other more or less.

Head heavily margined, both laterally and posteriorly above, the rim strongly emarginate or indented posteriorly, where it is also strongly elevated in life and darker than other portions of the head. Mandibles well developed, hook-shaped, situated in a buccal cavity, and crossing at tips; bases broad, with a rather large area for muscular attachment. Immediately back of the mandibles are two flattened, heavily chitinized organs, which are probably homologous to the

[1] Proceedings of the Linnean Society of London, vol. 1, pp. 317–320, 368–370.

maxillæ, but the minute character of which makes it impossible to determine their nature without considerable uncertainty. Head heavily armored with two powerful hooks or horns on the anterior margin, projecting laterally, about the size of the mandibles; above are seen two rather strong hooks at about the middle, both curved backward at tips; just back of hooks on dorsal portion of head are several semitransparent round spots, which probably bear small bristles, and may be sensory in function.

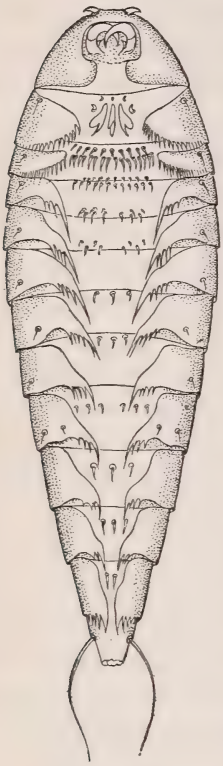

FIG. 24.—*Perilampus hyalinus:* Planidium, ventral view. Magnified about 350 diameters. (Original.)

Body segments as follows: First segment (excluding head) provided dorsally with two very minute semitransparent round spots, with dark spot in center, which is probably a minute spine, but which is rendered practically invisible by the clearing action of the balsam; ventrally the same segment is provided with two other similar spots, but which bear very distinct curved spines, one in the center of each. The heavy chitinous ring does not join beneath the body, each side ending instead with the ventro-posterior margin, which is serrated or fringed with long teeth, about 30 in number, becoming gradually shorter as they approach the lateral margin of the planidium. Between these fringed margins, situated in the center of the ventral portion of the segment, are three peculiar appendages which apparently function as ambulatory organs; these are somewhat flattened pyriform, with the broad end heavily notched somewhat at one side and attached at small end; at the bases of these are several small irregular appendages. The second segment is provided with the dorsal, backwardly curved spines, much closer together than on preceding segment and rather larger, and two ventral smaller spines; the teeth are slightly smaller. Between the serrate margins, as in preceding segment, are several hooks or motor appendages, but of quite a different type, these latter being simply plain hooks projecting backward, there being two transverse rows, about 10 in first row and about 16 in second. Between first and second segments on the

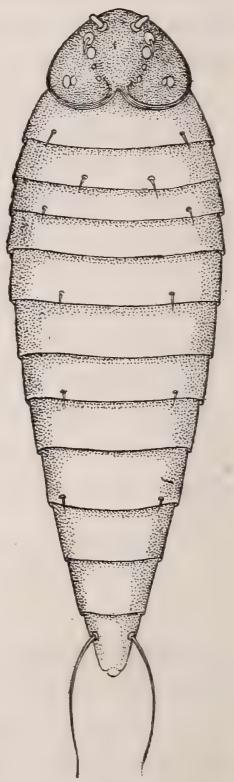

FIG. 25.—*Perilampus hyalinus:* Planidium, dorsal view. Magnified about 350 diameters. (Original.)

ventral side, situated in the elastic integument connecting the chitinized plates, are two stigmata, apparently the only spiracular openings in the whole tracheal system. Third segment similar to preceding, the two dorsal spines being considerably farther apart; the ends of the chitinous plate, however, are of quite a different type; instead of ending in a serrate margin the inner margin is smooth, but the posterior corner terminates in a long tapering projection considerably longer than the width of the chitinous sclerites; laterad of the long tapering projection referred to above are two or three much smaller ones, also situated on the apical margins of the segment; between the ends of the chitinous plates, as in preceding segments, are several hooklike motor appendages, smaller and fewer in number, however, than in the second segment; an additional series of hooks which is not provided in preceding segments is situated just laterad of these. The fourth segment seems to have no dorsal spines; there are two ventral ones, however, situated at the extreme outer margin of the ring; the chitinous plate terminates as in the third segment; motor appendages as in third segment but fewer in number. The fifth segment differs from the fourth apparently only in the possession of a pair of dorsal spines and in the smaller number of ventral motor appendages. The sixth segment does not have the dorsal spines but in other respects is similar to the fifth; the seventh segment possesses the dorsal spines; the eighth does not, nor does the tenth, eleventh, or twelfth; these latter, however, are similar in other respects, excepting that they become gradually less in size. The last segment is provided with an unjointed stylet on each side attached at about the middle of the segment, this stylet about twice the length of the segment itself.

HABITS OF PLANIDIUM.

Starting with the planidium upon the skin of the caterpillar, this makes its way through the thinner portion of the integument found at the junctures of the segments, this passage being effected by means of its well-developed mouth parts and speciallya rmored head. Just how the search for the host parasite is conducted is not known excepting as it may be deduced from dissections of preserved material. The planidium has been found in almost every part of the caterpillar and it appears that its search for a host is rather thorough and extensive. The time of its attack upon the host larva has not been very definitely determined, although from the data at hand it seems most likely that this follows at once upon the finding of another parasite within the caterpillar. This supposition is substantiated by the fact that the planidium is found within the very young tachinid larvæ which have just completed their first molt. In this stage the disparity in size between the larvæ of *Perilampus* and of *Varichæta* is very much less than it is later, and it seems remarkable that the

tiny tachinid maggot can, without inconvenience apparently, continue in its development with the *Perilampus* larva boring about within its body, and sometimes with not only one but five or six.

What becomes of the planidium in case the caterpillar does not contain a primary parasite is a question which has not yet been answered, and to do so would require considerable care and patience. There are two courses open to the *Perilampus* in case it has selected an unparasitized caterpillar. It may either wander about within the body of the latter until it dies from starvation and exhaustion, or it may make its way to the outside again and continue the search for a host in another caterpillar. That it might possibly develop upon the caterpillar itself is not to be considered. Even should it remain within the caterpillar until the latter pupated,[1] it is not likely that it could make its way through the hard pupal shell of *Hyphantria*, and if this were possible the older *Perilampus* larva is very much too delicate a creature to be able to feed externally unprotected.

In case the former alternative is what actually takes place, there must be a great percentage of mortality due to the lack of a proper host, for relatively only a small proportion of the caterpillars hatching from the eggs ever reach an age sufficient to nourish a host for *Perilampus*. Of those that do reach that age a great many are never attacked by primary parasites and hence would not be available for *Perilampus*.

Just what is the effect upon the caterpillar itself which is infested by *Perilampus* but which contains no primary parasite is a matter for conjecture. It seems likely, however, that its presence would not prevent the caterpillar from reaching its full development and it is probably only slightly inconvenienced if affected at all.[2]

Having followed the *Perilampus* planidium to its host within the caterpillar it is now necessary to trace out the slightly different modes of development upon the various parasites of *Hyphantria* which are subject to its attack.

Life as a Parasite of Varichæta.

Varichæta aldrichi Townsend [3] has been by far the most common of all of the parasites of the fall webworm in Massachusetts during the past two years. As stated on a preceding page, it belongs to that group of tachinids which deposit living maggots upon the stems and foliage in the vicinity of the caterpillars of their chosen host, a habit first discovered by Mr. C. H. T. Townsend in the course of his work

[1] Later dissection of *Hyphantria* pupæ, made in the spring of 1911, by Mr. H. E. Smith, discovered the planidium alive and still "waiting for something to turn up." In one instance the planidium was embedded in the gonad of the *Hyphantria*.—W. F. Fiske.

[2] The occurrence of the planidium in the gonad, as noted in preceding footnote, suggests that partial castration might possibly result.

[3] Determination furnished by Mr. W. R. Thompson.

at this laboratory and briefly described by him in an earlier bulletin of this bureau.[1] The maggots rarely leave their host until after it has become full fed and prepared for pupation in the fall. The tachinid maggots pupate soon after emerging from their hosts, the pupæ remain unchanged during the winter, and the subsequent transformations are accomplished quite early in the spring.

In case the planidium chooses a maggot of *Varichæta* as its host, it remains endoparasitic until the puparium is formed. During the process of histolysis the *Perilampus* either orients itself in such a manner that it will be external to the tachinid pupa when pupation is completed, or it emerges from the pupa immediately after pupation; in either case, of course, it remains within the puparium. When parasitic upon this host the planidium, so far at least as the writer has been able to learn, normally hibernates in this stage and probably without nourishment.

It is quite likely, however, that a late warm fall would start the development of the planidium on *Varichæta* at once. This would without doubt result in the death of the secondary parasite, as it would scarcely be able to pass the winter in the normal larval stage. In fact dead second-stage *Perilampus* larvæ have occasionally been found upon the pupæ during the winter, and this would seem to be evidence in corroboration of the above statement. It is probably an attempt to go through two generations per year, as this insect does, without much doubt, farther south, and the individual specimens found in the second stage during the winter in New England are probably those from the puparia which emerged as larvæ from the caterpillars earliest in the fall, although we have no absolute evidence that this is the case. The development, or rather the conduct, of the planidium up to and including its change from endoparasitism to ectoparasitism, as stated on a previous page, seems entirely dependent upon the development of its host, such are the intimate relations between the two. After the planidium has emerged from its host development takes place in the usual way.

As a Parasite of Limnerium validum Cresson.

Of the primary hymenopterous parasites attacked by *Perilampus* probably the most common one is *Limnerium validum* Cresson, an ophionine parasite emerging from the older caterpillars in the fall and hibernating as larva in a silken cocoon. The larva of this parasite, like that of *Varichæta aldrichi*, does not reach full maturity until its host has prepared for pupation, and the cocoons are to be found in the same situations as the pupæ of *Hyphantria* and are afforded the same protection. In this respect it differs radically from the other species of *Limnerium* parasitic upon the fall webworm.

[1] Technical Series, No. 12, Part VI, p. 103.

Perilampus hyalinus in this case always remains endoparasitic throughout the winter, at least so far as our observations go, and several hundred cocoons have been examined to date. At first it seemed rather puzzling that the same species should pass the winter ectoparasitically upon tachinids and endoparasitically upon *Limnerium validum*, but dissections of hundreds of the puparia and cocoons brought to light the fact that the habit of *Perilampus* in this regard was dependent entirely upon the life cycle of the host parasite, that is to say, the planidium lives internally in its host until histolysis takes place, when it changes its mode of life from an internal parasite to an external parasite. *Varichæta* pupates in the fall, so the planidium makes its exit at this season of the year and hibernates externally. *Limnerium validum* hibernates as a larva and pupates in the spring, hence the planidium in this case remains internal until spring, when it emerges by means of its efficient mandibles and spined head, completing its development in precisely the same manner as those individuals which happen to have chosen *Varichæta* as their host. The internal disturbances which take place in the body of the host at the time of histolysis probably act as a stimulus to the activities of the planidium, and the condition of the integument is such as to make the exit of the secondary parasite especially easy at this time. The development of the host, so far as our observations have gone, invariably ceases at the time of the exit of the planidium. Whether or not it is actually killed at this time is not evident. In any case decomposition does not take place immediately, the host being left in a condition somewhat comparable to that of the prey of certain aculeate Hymenoptera.

As a Parasite of Summer-Issuing Hymenoptera.

The other primary parasites of *Hyphantria* from which we have reared *Perilampus* are two additional species of *Limnerium*, differing from *L. validum* in that they spin their cocoon within the skin of the caterpillar and emerge in the fall, and the braconids *Apanteles hyphantriæ* Riley and a *Meteorus* (probably *M. communis* Cresson). In all four of these species the *Perilampus* completes its development at once. Whether or not these individual specimens manage to survive the winter is open to question. It is quite possible that many of them remain within the cocoon of their host throughout the winter. This is quite strongly indicated by the result of an experiment in which a collection of old webs containing cocoons of the several parasites was made on October 20, 1908, from which several adult *Perilampus* issued between 6 and 10 days later. The material was kept in a warm room; had it remained out of doors it is very unlikely that emergence would have occurred so soon, and probable that it would have been deferred until spring.

We know that the adult of one of the European species of *Perilampus* hibernates in the puparium of certain tachinids parasitic on the gipsy moth and brown-tail moth. Most of these tachinids, like the summer-issuing hymenopterous parasites, pupate comparatively early in the fall, thus making the two cases similar. For this reason the writer feels justified in surmising that the same thing occurs in the case of *Perilampus hyalinus* parasitic on the summer-issuing Hymenoptera.

As a Parasite of Other Hosts.

There is another group of parasites of the fall webworm which hibernate either as partially grown or as full-fed larvæ within the pupæ of their host. These include certain large solitary ichneumonids, *Anomalon ambiguum* Norton, *Ichneumon cinctitarsis* Provancher, and *Melanichneumon* sp. At least one species of Tachinidæ has also been found hibernating in this manner in Massachusetts. We have not actually found *Perilampus* to be a parasite of any of the ichneumonids named above, but only a very small number of the larvæ of these parasites have been seen.[1] There seems to be no good reason why the secondary should not attack these hibernating hymenopterous larvæ, and it is practically certain that the examination of a considerable number would show the planidium to be present.

We have absolute proof, however, that it does attack the hibernating tachinids,[2] having found the planidium actually within the maggot of this species within the pupa of *Hyphantria*. Whether or not the adult *Perilampus* is able to make its way through the pupal shell of the fall webworm (presuming that the tachinid completes its larval development and pupates internally) we are unable to state definitely, as no record has been made of *Perilampus* having issued from these pupæ. There seems to be little doubt as to its ability to do this, as it has very powerful jaws. Specimens in the laboratory will eat away quite a large quantity of cork in attempting to escape from a vial in which they have been confined.

LATER LARVAL STAGES.

On the return of warm weather in the spring, the winter having been passed upon the various hosts in the manner indicated in the preceding pages, the planidium begins feeding by sucking the juices of its host. Growth takes place gradually and first becomes apparent through the planidium taking on a banded appearance due to the

[1] It has since been found by Mr. H. E. Smith within the larvæ of *Ichneumon* (which attacks the pupa of the host) and that of *Exochilum*, which hibernate in what must be considered as an embryonic state within the *Hyphantria* pupæ.—W. F. Fiske.

[2] Probably *Compsilura concinnata*, the recently imported parasite of the gipsy and brown-tail moths.

separation of the chitinous rings or plates by a stretching of the intersegmental membranes which are transparent. (See fig. 26, *d*, *d'*.) The underside of the planidium also gradually fills out until the larva has attained a bulk several times greater than that of the hibernating planidium and presents the appearance of an ovate semitransparent sack with dark median crossbars dorsally.

After a short resting period, ecdysis takes place. The skin of the planidium breaks transversely just back of the second thoracic segment, the posterior segment slips backward, and the old head and first two thoracic segments are shed at the anterior end of the larva. Just how long the planidium feeds before ecdysis has not been ascer-

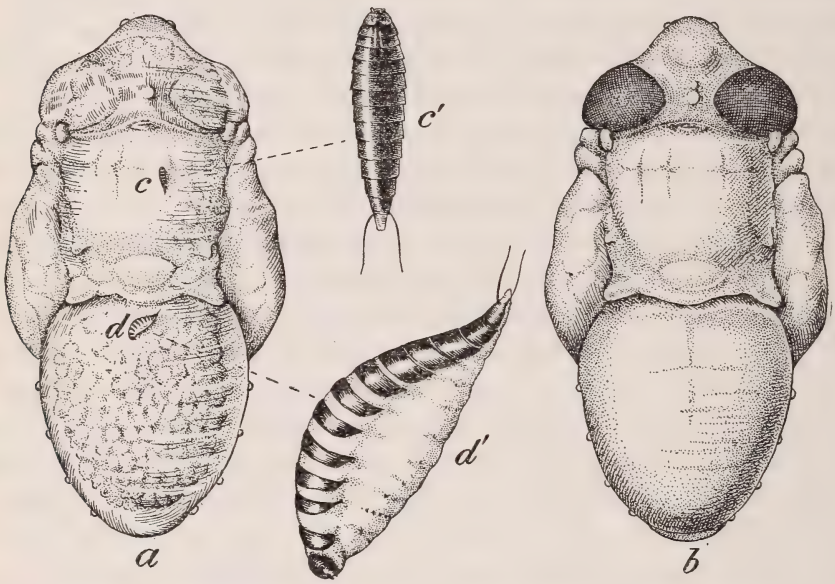

FIG. 26.—*a*, Pupa of *Varichæta aldrichi* parasitized by *Perilampus hyalinus;* *b*, unparasitized pupa of *Varichæta aldrichi;* *c*, planidium of *Perilampus hyalinus* before feeding; *c'*, same, more enlarged; *d*, planidium of *Perilampus hyalinus* after feeding; *d'*, same, more enlarged. (Original.)

tained. The period probably varies greatly in accordance with the prevailing temperature. Usually, though not always, the larva crawls away a short distance before it resumes feeding.

After settling down the second time it is likely to remain stationary for the rest of the larval and the pupal life. The larva in the second stage is of a whitish color, with the tracheal system showing through the transparent skin. The body is ovate in shape, with the head bent underneath the anterior portion. The growth during this stage is little compared to that accomplished in the third, and after feeding a short time the second ecdysis takes place.

Growth now becomes quite rapid and the larva assumes a very different appearance. (See fig. 27.) The mandibles have not increased in size to any great extent, but the mouth as a whole and the head

change quite materially. The mouth parts are in this stage situated in a triangular basinlike depression which is bounded on two sides and parts of the third by a strong chitinous carina or rim. Besides the mandibles there are two bulblike appendages just beneath, which are probably homologous to the maxillæ of the adult. Immediately above the oral opening are situated two large rounded elevations which may be called larval antennæ. The segments forming the head are now separated by a more or less distinct neck from the remaining segments and are bent beneath them with face downward, as in the second stage. The first two thoracic segments are each provided laterally with a raised tubercle at about the middle of the segment, viewed from the side, and just above this tubercle is another more or less distinct one, one also occurring on the third thoracic segment in a corresponding location. The next three segments each bear a pair of much larger tubercles or projections which give the larva a very unusual appearance. These tubercles, if they may be called such, correspond to those described and figured by Dr. Wheeler as occurring in *Orasema,* but are somewhat differently arranged. Just posterior to these there occurs an abrupt declivity, the segments becoming much smaller toward the posterior end of the larva. Beneath, the larva is smooth and free from constrictions, but the segmental sutures are visible to some extent. Dorsally through a transparent median line formed by a break in the corpus adiposum may be seen a large number of white urate masses, which pulsate slowly back and forth as the larva feeds. The tracheal system is rather conspicuous and is of the normal holopneustic type.

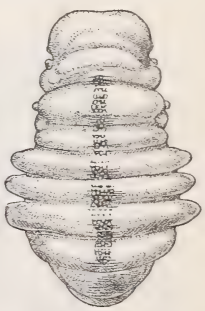

FIG. 27.—*Perilampus hyalinus:* Mature larva. Greatly enlarged. (Original.)

PUPATION.

(Figs. 28, 29.)

As soon as the larva is full fed, pupation takes place. The meconium is discharged, leaving the larva scarcely more than half its former bulk, and creamy white instead of translucent gray-white in color. Beneath the larval skin the imaginal appendages and the head gradually appear, and the tubercles so characteristic of the larva become less conspicuous. Finally the larval skin is discarded, and the pupa assumes its own distinctive shape.

The pupa is short and robust, corresponding very closely, of course, to the form of the adult. The abdomen bears five or six transverse carinæ or ridges, one for each segment, which are interrupted on the disk. These are very similar to those occurring on the ant parasite *Orasema viridis,* but differ in that they are not continuous dorsally

At first the pupa is white or yellowish white, but the eyes soon become pigmented with reddish, then the thorax becomes black, later changing to a metallic green. In about two days the head and abdomen assume the same metallic hue as the thorax, with the sculpture of the adult insect showing through, and soon after this the pupal skin is shed and the adult insect issues.

FOOD HABITS OF THE ADULT.

No observations upon the food habits of the adult *Perilampus* have been made in connection with this work, excepting that in confinement they will consume, in common with many other chalcidoid parasites, comparatively large quantities of sweetened water upon banana peelings. During June, 1905, the author found specimens of this genus in abundance upon the leaves of *Ambrosia, Helianthus,*

FIG. 28.—*Perilampus hyalinus:* Fresh pupa. Greatly enlarged. (Original.)

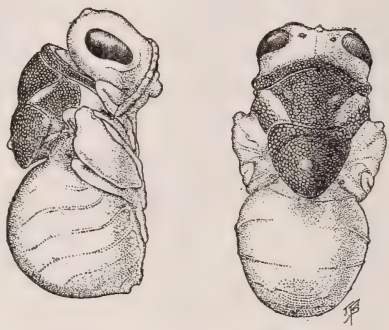

FIG. 29.—*Perilampus hyalinus:* Pupa just previous to eclosion. Greatly enlarged. (Original.)

and other vegetation at West Point, Nebr., where they were apparently feeding upon the honeydew secreted by aphides.

Dr. S. Graenicher, of the Public Museum of Milwaukee, has in the course of his extensive studies upon the pollination of Wisconsin flowers [1] recorded two species of *Perilampus, hyalinus* Say and *cyaneus* Brullé, as visitors of the following Compositæ: *Eupatorium perfoliatum, Solidago juncea, S. canadensis, Achillea millefolium, Tanacetum vulgare,* and *Erigeron canadensis.* In considering the insect visitors to the last named flower he has the following to say:

> It is noteworthy that the chalcid-flies *Perilampus cyaneus* and *P. hyalinus* seem to have a certain preference for these flowers. They were regular attendants, day after day, at Cedar Lake, and were also present at Milwaukee.

Dr. Graenicher in a recent letter kindly informs me that he has also taken *P. cyaneus* at flowers of *Angelica atropurpurea, Pastinaca sativa,* and *Sium cicatæfolium.*

[1] Bulletin of the Wisconsin Natural History Society, vol. 7, Nos. 1 and 2, pp. 19–77, April, 1909.

LONGEVITY AND OÖGENESIS.

While the *Perilampus* adults as a usual thing are very short-lived in the laboratory, there is no doubt that they live for a considerable period when out of doors under natural conditions. This is indicated by the fact that the females, when newly emerged, never contain eggs within the ovarian tubes, as do those insects which oviposit at once upon emerging.

In one instance a female was kept alive from April 6 to May 12, a period of 36 days, at the end of which time she was apparently ready to oviposit. Upon dissection approximately 250 eggs, nearly all of which seemed to be ready for deposition, were found. It is probable that many more would have developed had the individual remained alive under natural conditions.

LENGTH OF LIFE CYCLE AND INFLUENCE OF TEMPERATURE.

The time required for *Perilampus* to develop from egg to adult is dependent upon several factors, one of the most important of which is the host. When parasitic upon *Varichæta*, the planidium begins to feed early in the spring. On *Limnerium validum*, however, the planidium must wait until its host begins pupation before it can become external, thus throwing it several days or even weeks behind the individuals infesting *Varichæta*.

There are no complete data at hand concerning the development upon *Limnerium*, owing to the failure of any individual to complete its transformations upon this host after removal from the cocoon. Its progress has been followed beyond the first ecdysis several times in the laboratory. In an apparently typical instance a larva of *Limnerium* containing two planidia was brought into the laboratory from out of doors on January 28 and placed in an incubator kept at a temperature of 78° F. On the morning of February 4 histolysis had begun, and during the evening of February 5 both planidia had made their exit. Two days later the host larva was apparently dead and the planidia were feeding. February 11 one had molted its first-stage skin, but died a short time later.

With *Varichæta* as a host it is a much simpler matter to carry the *Perilampus* through to maturity. When a single individual is watched through its development more time is required than in undisturbed puparia, owing to the fact that it is impossible to keep the host pupa from deteriorating somewhat. A typical instance of the development upon *Varichæta* under laboratory conditions follows: On January 28 a pupa of *Varichæta* with a single planidium was brought in from out of doors and placed in the incubator. On the next day the planidium had started to feed and filled up rapidly. February 1 the distance between the dorsal plates of the planidium

was rather greater than the width of the plates themselves. Three days later the first ecdysis was completed and the second-stage larva had moved some distance away from its original feeding place. The next day it had become very much distended and glistening. On February 7 it had apparently molted a second time and was very strongly tuberculate. On the 9th it was again feeding freely. Five days later it had reached full growth and ceased feeding. The next day pupation had taken place, but the pupa was still pale in color and covered with little "perspirationlike" globules. On the 19th the thorax of the pupa had begun to turn dark and the sculpture of the adult to show, and three days later it had become entirely dark colored. On February 25 the adult *Perilampus* emerged. The time required for development from start of external feeding to maturity was 28 days. The incubator was kept at a constant temperature of 78° F.

In the unopened puparia brought in at the same time *Perilampus* required about 25 days from the time they were placed in the incubator until they emerged as adults, but the period of development is dependent somewhat upon how much time they have been left out of doors, and there is some variation among the individuals themselves. From puparia brought in and placed in the incubator November 22 to 28 *Perilampus* began emerging December 27, about a month later, and continued coming out intermittently until approximately February 13, covering a period of about 48 days. Puparia brought in December 13 to 19 produced *Perilampus* first on January 17 and continued producing until February 6, a period of about 20 days. Puparia brought in January 17 to 23 produced adult *Perilampus* first on February 14 and continued until March 3, a period of about 17 days. From the above data it is seen that the later in the winter the puparia are brought in and placed under conditions favorable for the development of *Perilampus*, the shorter is the period during which the adults emerge. It is also evident that when infested puparia are brought in early in the winter a longer period of time elapses until the first adult *Perilampus* emerges than when left for a more extended period out of doors. Whether bringing the planidium in later in the winter causes it to develop more rapidly or whether it simply does not require so much time before becoming ready to begin feeding under these conditions is not known, but the latter explanation seems more reasonable.

The relative time of emergence of the adult *Perilampus* and adults of the host insect of the same lot is of considerable interest and will be given more study later. In September, 1908, a lot of *Varichæta* were placed in cold storage and kept there until January 18, when they were brought into the laboratory. From these puparia *Vari-*

chæta adults issued from February 2 to February 14. *Perilampus* adults issued from the same lot April 1 to April 6, approximately two months later.

In this instance the puparia were not kept at an even temperature. During the night, especially, it was frequently cool. Another lot of puparia collected at about the same time but *not* placed in cold storage or exposed to frost produced *Perilampus* adults November 30 to January 30 and adult tachinids January 22. Under these conditions the first *Perilampus* issued a month *earlier* than its host, as opposed to two months *later* when kept in cold storage until about the middle of January. It is apparent from the above that *Perilampus* adapts itself to changed conditions much more readily than does *Varichæta*. Indeed it is a necessity that it should be able to do this, being a parasite of other parasites which normally complete their development during either spring, summer, or fall, as the case may be.

EFFECT OF PARASITISM UPON HOST.

(Fig. 26.)

The *Perilampus* planidium, even before it begins to feed, exerts a very marked effect upon its host, especially in case the host is a tachinid. As mentioned on a preceding page, these planidia while living internally within the host larva do not seem to cause it the slightest inconvenience, and it is impossible to distinguish between a parasitized and an unparasitized larva before the planidium emerges, excepting, of course, where the secondary parasite itself is visible. Immediately pupation takes place in the host and the planidium becomes ectoparasitic, the effect of the parasitism becomes evident, especially after the host pupa has been subjected to warmth. Instead of responding to the increased temperature in the usual way—that is, instead of developing pigment in the imaginal eyes and bristles upon the body—it takes on a peculiar transparent appearance, principally in the cephalic and thoracic regions. The eyes and appendages develop very slightly and the imaginal head reaches scarcely one-half the size of that attained in the unparasitized pupa. These pupæ now present a very characteristic appearance (see fig. 26), and in opening a series of puparia one may recognize the parasitized individuals at a glance, even before *Perilampus* has begun to feed. This peculiar effect is noticeable to a considerably less extent where *Limnerium* acts as a host.

The pathological nature of this unusual condition of the parasitized pupæ has not been investigated as yet. It is apparently an arrested histogenesis, but in what manner this is brought about we can not say. Only a single case has come under observation where

the host pupa developed the characters of the adult to any extent. During March, 1909, a puparium of *Varichæta* was dissected and found to contain a very small pupa of *Perilampus,* only about three-fourths natural size but fully developed and apparently healthy in every way. The astonishing thing in this instance was the fact that the tachinid pupa had developed to a stage where it had taken on the characters of the adult. Even the bristles were well formed. This is the only case out of several hundred puparia examined where development had not ceased soon after the formation of the pupa and is rather difficult to explain. It is possible that for some reason the planidium did not respond to the usual stimulus, histolysis, and remained internal within the pupa, giving the tachinid an opportunity to develop considerably further than normally before the secondary parasite changed its mode of life to external feeding. There were many other puparia subject to the same conditions and they all responded in the usual way, so that the above case must be considered as abnormal.

The retardation of development in the parasitized hosts is of course brought about by the presence of the planidium, but whether indirectly or directly has not been ascertained. That it may be due to a glandular secretion is not impossible, but this hardly seems to be an adequate explanation, as nothing resembling glands of this kind have been found, although a careful study of the planidium has been made with the oil-emersion objective. In the opinion of many zoologists an insect during the process of pupation is in a very critical condition and is more susceptible to injury at this time than during any other period of its life. It does not seem improbable that in this supposition lies the explanation of the condition brought about in its host by *Perilampus.* The larva or maggot is able by reason of its great vigor to withstand the presence of the secondary parasite, but immediately histolysis and histogenesis begin to take place the weakened condition of the host makes itself apparent in the form of a cessation of development of pupal or imaginal organs and appendages and occasionally in certain instances death ensues. The development of *Limnerium* invariably ceases soon after the exit of *Perilampus,* although the latter does not emerge until the host larva has discharged its meconium and the formation of the pupa has begun. In one instance the planidium was observed located in the imaginal eye of its host, which becomes visible as a darker spot some time before the larval skin is discarded.

PERCENTAGE OF PARASITISM.

The percentage of parasitism of *Varichæta* and *Limnerium* by *Perilampus* in 1908 was not very high. Large numbers of the cocoons and puparia were opened, or reared through in the laboratory,

but accurate counts were kept in only a single instance, in which 35 out of a lot of 164 puparia, or 21.4 per cent, were found to be parasitized by *Perilampus*. This is known to be above the average, taking the material which was reared or studied as a whole.

The results of several counts given in Table I are indicative of parasitism in 1909.

TABLE I.—*Percentage of parasitism of Varichæta by Perilampus, 1909.*

Number of puparia.	Number attacked by Perilampus.	Per cent of parasitism.
29	16	55.0
244	58	23.3
57	28	49.1
100	54	54.0
100	23	23.0
Total.....530	179	.....
Average.....	.....	41.0

The variation between the individual lots is due to their having been collected in different localities. Although it may be stated with assurance that the average was much higher than during the previous year, exact comparisons are impossible, since parasitism varies in different nests in the same locality, and in different localities. A long series of careful calculations would be required in order to secure accurate results.

As might be expected, the cocoons of *Limnerium validum* were parasitized to an approximately equal extent, and in these cocoons were found a few planidia of another species, which has been designated in the notes as "Species A." The summer-issuing *Limnerium* and *Apanteles* were not so heavily parasitized as a rule, probably because many of the planidia did not enter the caterpillars until a part of those afflicted by these parasites had died.

The percentage of healthy caterpillars of *Hyphantria* bearing the planidia, either internally or externally, ought to be, and apparently is, approximately the same as the percentage of *Varichæta* and *Limnerium* parasitized.

SUPERPARASITISM.

PERILAMPUS VERSUS PERILAMPUS.

The extent to which *Varichæta* or *Limnerium* is parasitized by *Perilampus* may be easily determined by opening the puparia or cocoons before the planidia have begun to develop, and in this manner the prevalence of superparasitism may be easily calculated. Upon several occasions as many as five planidia have been found upon one host, and four, three, and two are of frequent occurrence. In not a

single instance out of hundreds has more than one adult *Perilampus* issued from any cocoon or puparium under observation.

In a recent discussion of this phase of parasitism by Mr. W. F. Fiske [1] an attempt was made to classify its varied manifestations in accordance with the manner in which the parasites interested are ultimately affected. Superparasitism by *Perilampus* appears to fall in "I, b." of the scheme, i. e., one parasite lives and the other or others die, and the survivor brings about the destruction of the others by causing the premature death of the host. Several planidia may begin to feed at about the same time, but one invariably molts for the last time a little in advance of the others, and even though the difference is but a few hours it quickly devours the host, or else reduces it to such a condition as to render it unfit food for the next in succession. In no case has one larva been known to make a direct attack upon another.

In the article referred to above an attempt was made to indicate diagrammatically the probable amount of superparasitism accompanying a given amount of parasitism provided its prevalence was governed by chance alone. Whenever opportunity has permitted, the validity of the calculations which served as the basis for this diagram has been tested, and in nearly every instance, to date, the results have tended to confirm the contention at the time that "in the field * * * superparasitism would be distinctly more prevalent in proportion to the percentage of total parasitism" than these calculations demanded. This has proved to be true of *Perilampus*, as will be seen by Table II, which gives the results of a series of counts to determine the point.

TABLE II.—*Prevalence of superparasitism of Perilampus on Varichæta, 1909.*

	Lot 1.	Lot 2.	Lot 3.
Puparia examined.....number..	100	100	57
Perilampus planidia found.....do....	28	87	47
Supernumerary planidia.....do....	5	33	19
Puparia parasitized.....do....	23	54	28
Parasitism.....per cent..	23	54	49
Loss in efficiency through superparasitism:			
Actual.....do....	5	33	33
Theoretical[1].....do....	3.3	28.8	26.6
Losses sustained by Perilampus through superparasitism:			
Actual.....do....	17.9	37.9	40.2
Theoretical[1].....do....	11.8	33.1	32.4

[1] In accordance with calculations upon which the diagram published in the Journal of Economic Entomology (loc. cit.) was based.

It will be noted that in each instance the numerical loss sustained by *Perilampus*, and the decrease in its efficiency as a parasite, is greater than is theoretically called for.

[1] Journal of Economic Entomology, vol. 3, pp. 88–97, 1910.

Perilampus versus Dibrachys.

Another exceedingly curious complication was observed in the winter of 1908–9 in an instance where a cocoon of *Limnerium validum* had been attacked by *Perilampus* and later by *Dibrachys boucheanus* Ratzeburg. The larvæ of the latter parasite fed externally and gregariously, and hibernated without transforming to pupæ. So soon as its original host was destroyed, the *Perilampus* planidium, not to be outwitted, calmly proceeded to take up a position internally in one of the *Dibrachys* larvæ. The particular larva bearing this planidium was killed and preserved, but in another instance a very small *Perilampus* adult issued from a puparium of *Varichæta* from which a number of *Dibrachys* adults had emerged some time before, and there is no doubt that it completed its transformations as a parasite on this host. With the exception of *Melittobia*, which from its very small size would likely prove unsuitable as an ultimate host, there is no known hymenopterous hyperparasite likely to attack the puparia of *Varichæta* or the cocoons of *Limnerium* which might not serve as well as *Dibrachys* as a host for *Perilampus*. The planidium is admirably fitted to triumph over adversity, and shows the part of wisdom in not causing the death of its host until it is ready to complete its transformations. If, for example, it had the habit of killing its host in the fall, and of hibernating as a full-fed larva, after the manner of *Dibrachys*, the latter might easily turn the tables and emerge victorious from the conflict.

PERILAMPUS, "SPECIES A."

(Figs. 30, 31.)

In the course of the investigations upon the genus *Perilampus*, two kinds of planidia have been found parasitic upon *Limnerium validum*, which, while belonging to the same general type, are quite different in structural detail and apparently represent different species. One of these, the commoner one, is *Perilampus hyalinus*, which has been treated rather fully in the preceding pages. The other species we have never succeeded in rearing through to the adult, so are unable to give it a specific name at this time. In length it is rather shorter than *hyalinus*, measuring on the average about 0.24 mm., but is comparatively greater in diameter through the anterior segments. The color is usually somewhat darker than that of *hyalinus*. In *P. hyalinus* the head of the planidium is notched or emarginated and elevated posteriorly, but in this species the posterior margin is continuous. The mandibles are heavier and considerably less curved, and the recurved hooks on the top of the head are also considerably larger. The ambulatorial spines are very much less developed than

in *hyalinus* and the ends of the chitinous bands which surround the body are simple, not terminating in long teeth or serrate as in the other species. The dorsal and ventral bristles, however, are stronger and more numerous, and somewhat differently arranged.

Considerable difference in habit in these two species has also been noted. *P. hyalinus*, we have reared from many different hosts, but the other species has been found only upon the larva of *Limnerium validum*. Instead of remaining internal within the *Limnerium* larva until it attempts to pupate in the spring as does *P. hyalinus*, this species, if it ever feeds endoparasitically, must emerge from its host soon after the cocoon is spun, for it is found externally upon its host during the fall and winter before the *Limnerium* has any intention of pupating, and has never been found internally. In only one instance have we succeeded in getting this species to feed, and even that did not terminate satisfactorily. During the spring of 1909 a specimen of the planidium of this species was placed on a larva of *Limnerium* in a glass cell for observation. Six days later the planidium had not fed and was noted as being apparently dead, but on the next day it was seen to have been feeding, although its host was still alive and active. Five days later the planidium had molted its skin and had taken on the globular form of the second-stage larva but was apparently not in very good condition and died two or three days later. At no other time were we able to get this species to feed. There is a possibility that it is of purely accidental occurrence upon *Limnerium*, and this may account for our inability to rear the adults. This belief is strengthened by the fact that a large percentage of the specimens of this planidium are

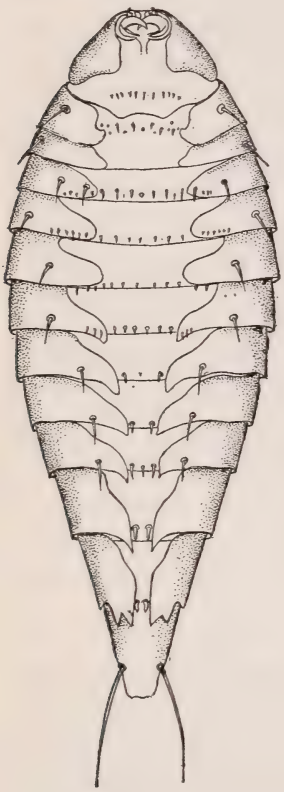

FIG. 30.—*Perilampus*, "species A:" Planidium, ventral view. Magnified about 400 diameters. (Original.)

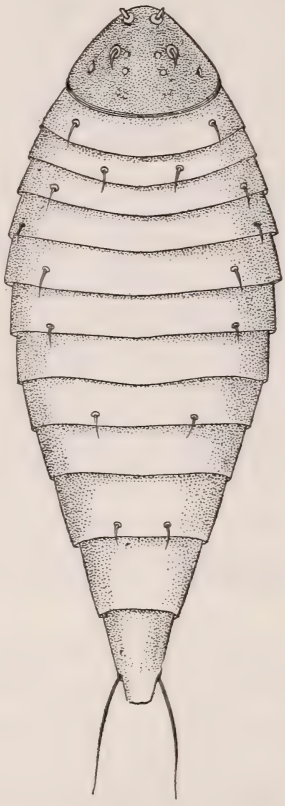

FIG. 31.—*Perilampus*, "species A:" Planidium, dorsal view. Magnified about 400 diameters. (Original.)

dead when found upon the *Limnerium* larvæ in the fall. Out of 11 specimens found during an examination of some 55 cocoons, 10 were dead and shrunken. These cocoons had been kept under perfectly natural conditions out of doors, so that it is obvious that there was something radically wrong between parasite and host. The fact that it has never been found upon *Varichæta* suggests the possibility of its being of ectoparasitic habits entirely, and that it attaches itself to the *Limnerium* larva after the latter emerges from the caterpillar, but prior to the spinning of its cocoon. This would of course preclude its being a parasite of a tachinid, as the formation of the puparium would naturally leave it outside of the hardened shell and death would inevitably result. The data on hand concerning this species, however, are too limited to warrant an attempt to draw any conclusions, and with the recording of the above facts we leave it until further investigations have thrown more light upon its habits.

DEVELOPMENT OF ORASEMA.

Dr. William Morton Wheeler, in the article referred to on page 35, gives an exceedingly interesting account of the life history and economy of the chalcidoid genus *Orasema*, of the family Eucharidæ. A comparison of the habits of representatives of the so-called families Eucharidæ and Perilampidæ is of unusual interest at this time and may assist in clearing up certain doubtful points in the economy of the former. *Orasema* is parasitic principally upon the harvesting ant *Pheidole instabilis* Emery, but also occurs not uncommonly upon representatives of other ant genera in the southwestern United States and Mexico. In view of the close relationship existing between the two genera and the general similarity of development so far as is known in the two forms, it would seem permissible at this time to draw certain conclusions in regard to *Orasema* which have been suggested by the investigations upon *Perilampus*. In regard to the oviposition of *Orasema* Dr. Wheeler has the following to say:

> I have not seen the eggs of *O. viridis* after oviposition, but only the very young larvæ. Dissection of the female shows that, as we should expect in a parasite, the eggs are extremely numerous and minute. The mother insect, when she comes to oviposit, exercises a very careful selection among the ant brood. In the first place she has nothing to do with the *instabilis* larvæ, but directs her attention to the pupæ. In the second place she selects, as a rule, only the pupæ of the soldiers, males and females. The small worker pupæ would not furnish sufficient food for her larvæ. In the third place she selects only pupæ at the very critical moment when they have been stripped of their larval skin by the workers and are, therefore, little more than semipupæ, for obviously at this moment the cuticle is thinner and will be more easily pierced by the young *Orasema* larvæ than during the preceding or succeeding stages; and in the fourth place she does not lay her eggs at random anywhere on the body of the semipupæ, but carefully selects one of four regions near the head. Usually she places the egg on the sternal surface just beneath the very short, incurving legs of the

semipupa, but occasionally it is placed on the back of the neck between the head and the prothoracic segment or on the right or left side of the neck beneath the corresponding prothoracic leg. These regions would seem to be singularly appropriate, both because the cuticle is extremely thin and readily punctured by the parasitic larva at these points, and also because the egg or resulting larva, especially when it is covered with the overlapping appendages of the semipupa, is not so readily brushed or licked off by the *instabilis* workers.

If we may judge from the habits of *Perilampus*, the explanation of Dr. Wheeler's failure to find the eggs of *Orasema* in the ant nest is possibly that they are not deposited there. It is possible that oviposition might take place outside the nest, perhaps upon flowers or other vegetation visited by both the *Orasema* adults and the worker ants; and that from the eggs deposited upon these plants the planidia hatch, in some manner attach themselves to the worker ants, and are in that way conveyed to the nest, where they leave their carrier and attack the larvæ. Several points in the economy of *Orasema* as noted by Dr. Wheeler tend to substantiate the belief that oviposition takes place outside the nest. In the first place the large number of eggs deposited by *Orasema* (Dr. Wheeler found by dissection of the adults that they were very numerous and minute) indicates that somewhere in its early life cycle there is prevalent a very great mortality. That this mortality actually takes place was observed by Dr. Wheeler, and he thought that it might be explained in the following manner:

I believe that the danger of detaching the egg is very great, and this, together with the other special requirements enumerated above, may account for the fact that comparatively very few of the great number of *Orasema* eggs ever complete their development.

The number of eggs deposited by a single female *Orasema*, should they all become effective, would probably be sufficient to annihilate a whole colony of the *Pheidole*, and not one but many female *Orasema* are usually found in the infested nests. It would seem, therefore, that there would be little likelihood that such great mortality would occur if only the causes enumerated by Dr. Wheeler were operative. It is possible that the *Orasema* planidia attack the larvæ of *Pheidole*, not the pupæ, and that the seemingly sudden appearance of the young *Orasema* larvæ upon the pupæ of *Pheidole* immediately after the last larval ecdysis is similar to that which has been noted on a preceding page as occurring in *Perilampus*. In other words, the *Orasema* planidium may be endoparasitic within the *Pheidole* larvæ, making its exit to the exterior at the time of histolysis and feeding ectoparasitically thereafter. Dr. Wheeler's observation of the fact that the *Orasema* planidia appear upon the pupæ only at this critical time would tend to substantiate this theory.

It seems improbable that insects as highly positively phototropic as Dr. Wheeler has observed *Orasema* to be should return to the interior of an ant's nest to oviposit after having escaped and lived in the sunlight for a considerable time.

PLANIDIUM OF ORASEMA VIRIDIS ASHMEAD.

Length about 0.16 mm. General shape like that of *Perilampus*, but comparatively broader and much more simple in structural detail. Color dark, as in *Perilampus*. Head more elongate than that of *P. hyalinus*, the recurved hooks, if present, very small; there are two pairs of organs in a location similar to that of the hooks upon the head of *Perilampus*, but their extremely minute size makes the nature of these objects difficult to define even under the oil-immersion objective. Mouth parts indefinable, considerably retracted into head. Anterior margin of head much roughened. First dorsal segment short, with a pair of distinct bristles situated along the apical margin, the base of each within a transparent spot. Second segment broader, with two apical spines farther apart than on preceding. Next segment much like second, but broader, with similar spines. Remaining segments apparently without dorsal spines. Ventral ends of the chitinous plates simple, not ending in a serrate margin or with long teeth as in *Perilampus*. Seventh segment with a pair of spines ventrally. Last segment with a pair of stylets comparatively shorter and stronger than in *Perilampus*.

Dr. Wheeler's account of the effect of parasitism by *Orasema* upon *Pheidole* tallies very well with our observations upon parasites attacked by *Perilampus;* the same microcephalic characters are present in the host pupæ in both cases, with the peculiar transparent appearance, as noted upon a previous page of this article.

Other points in the economy of *Orasema* brought up by Dr. Wheeler and which at the time seemed very puzzling are apparently rather easy of explanation in the light of our present knowledge of *Perilampus*. It is hardly within the province of this bulletin, however, to take these up in detail, and it is merely suggested here that anyone desirous of doing further work upon the development of *Orasema*, and perhaps other members of the chalcidoid family Eucharidæ, would perhaps do well to bear in mind the similarity of the life cycle, so far as known, to that of *Perilampus*.[1]

RELATIONSHIP OF EUCHARIDÆ AND PERILAMPIDÆ.

The great similarity of development in the genera *Orasema* and *Perilampus* can not fail to have considerable bearing upon the taxonomic relationship of the so-called families Eucharidæ and Perilampidæ. Francis Walker, in 1846, placed the two groups together under the family name Eucharidæ. Ten years later, however, the German hymenopterist, Arnold Förster, decided that the differences

[1] During the winter of 1909–10 an extraordinary planidium was found on the hibernating larva of the larch sawfly (*Nematus erichsonii* Hartig), within the cocoon. This parasite was not reared, but was *Perilampus* in all probability.

were sufficient to justify him in splitting the group into two distinct families. In this move he was later supported by Dr. William H. Ashmead. It is of course impossible to come to any definite conclusions in a case of this kind until more has been learned concerning the larval development in the other genera of the two groups, and also in the related families. If it is found that this type of development is characteristic of these two groups and no others, it should certainly be an argument of considerable weight in support of Walker's views.

RHIPIPHORUS AND OTHER COLEOPTEROUS PARASITES.

Anyone at all familiar with the life histories of certain of the parasitic Coleoptera, *Meloë*, *Sitaris*, and more especially the hornet parasite *Rhipiphorus*, will be reminded of these genera by a perusal of the preceding pages. The similarity in development, life cycle, and habits even to certain minute details is so striking that one in reading the excellent description of the life history of *Rhipiphorus paradoxus* given by Dr. T. A. Chapman [1] could scarcely tell whether it belonged to that insect or to *Perilampus* were the names omitted. A brief comparison of the two may be of interest.

So far as we know, the place of oviposition of *Rhipiphorus paradoxus* has not been observed, but other members of the family, notably *Myodites*, oviposit commonly upon flowers of various kinds. From the eggs hatch the triungulins which are not only analogous to the planidium of *Perilampus* and *Orasema* but, except for the legs and antennæ, are strikingly similar in anatomical details. The dark chitinous rings which encircle the triungulin for protective purposes during its adventurous search for its host, the backward-pointing spines with which these are provided, the pair of stylets on the last segment and the "comma"-shaped mandibles retracted into the buccal cavity all forcibly remind one of the planidium of *Perilampus*. The writer is aware that the resemblance is mainly a superficial one, but it is very unusual, superficial though it be. The similarity does not end here, however, but is carried out even to the details of the life cycle. It is more comparable to *Orasema* than to *Perilampus* inasmuch as the *Perilampus* is a secondary while the others are primary parasites. The *Rhipiphorus* triungulin, after gaining entrance to the nest of its host, conducts itself almost exactly as we have reason to suspect *Orasema* does; that is, it enters the young host larva, emerges at the time the host larva attempts to pupate, and feeds ectoparasitically thereafter. It differs, however, in the fact that the *Rhipiphorus* triungulin feeds and grows to 8 or 10 times its original length while *within* the host larva, while *Orasema* and *Perilampus* apparently do

[1] Annals and Magazine of Natural History, 4th series, vol. 6, pp. 314–326, 1870.

not grow at all until they emerge and begin feeding outside. This resemblance is not altogether lost in the later stages. Even the large dorsal tubercles or projections of *Orasema* and *Perilampus* are reproduced in the third-stage larva of *Rhipiphorus*. There is a slight difference in the method of pupation, the *Rhipiphorus* larva leaving the host to pupate while *Orasema*, when not interfered with by the worker ants, and *Perilampus*, transform *in situ*.

We have then in *Perilampus* and *Orasema* an instance of hypermetamorphism as defined by Packard, belonging to the same type as that occurring in the Rhipiphoridæ. The planidium exists as such because of the wandering and perilous life it is obliged to lead in its search for a host, but soon after that host is found, the protection of the chitinous plates or the use of the ambulatorial spines no longer being necessary, these accessory structures are discarded. As the parasite now has easy access to an abundance of rich nutritious food without the necessity of putting forth the slightest effort it becomes a mere grub—a perfect adaptation to the new mode of life.

HOST RELATIONS OF THE GENUS PERILAMPUS.

REARING RECORDS OF PERILAMPUS HYALINUS AT THE LABORATORY.

We have found the native species *Perilampus hyalinus* to attack the primary parasites of two species of Arctiidæ, *Hyphantria textor* Harris and *Euchætias egle* Drury; a single notodontid, *Melalopha inclusa* Hübner; and a saturniid, *Samia cecropia* L.

The species *hyalinus* has shown an adaptability in the matter of food habits which is quite unusual in an insect with such a complicated life history. We have absolute records of this species from 10 different primary parasites belonging to 2 different orders and 6 or 7 different genera. A diversity of host relations as exhibited by *hyalinus* would not be considered at all remarkable in species of a great many chalcidoid genera, but when we consider the circumscribed method by which access to the host is gained, it seems, on first thought, to show a quite unusual versatility. When we come to analyze the habits of the parasite more closely, however, it is at once seen that the versatility is only apparent. The diversity of host relations is due more to a lack of discrimination than to any especial adaptability. Precisely the same efforts are put forth by the planidium on the occasion of its attack upon any and all of its hosts. The conditions under which it develops are somewhat variable, but even here the actual stimulus which causes the change from endoparasitism to ectoparasitism is the same, namely, that of histolysis in the host larva.

We have reared *P. hyalinus* from the following hosts:

PARASITES OF HYPHANTRIA TEXTOR HARRIS.

Tachinidæ:
Varichæta aldrichi Townsend.
Compsilura concinnata Meigen.
Ichneumonidæ:
Limnerium validum Cresson.
Limnerium fugitivum Say.
Limnerium pallipes Provancher.
Braconidæ:
Apanteles hyphantriæ Riley.
Meteorus communis Cresson.
Pteromalidæ:
Dibrachys boucheanus Ratzeburg (on *Varichæta*).

PARASITE OF EUCHÆTIAS EGLE DRURY.

Tachinidæ:
Genus and species undetermined.
Braconidæ:
Apanteles sp.

PARASITE OF MELALOPHA INCLUSA HÜBNER.

Ichneumonidæ:
Limnerium validum Cresson.

PARASITE OF SAMIA CECROPIA LINNÆUS.

Tachinidæ:
Frontina frenchii Williston.

OTHER AMERICAN REARING RECORDS OF PERILAMPUS.

Through the courtesy of Dr. L. O. Howard the rearing records have been obtained from the collection and biological notes of the Bureau of Entomology. The species of *Perilampus* have not been determined. The hosts are all lepidopterous and are as follows:

Dasypyga alternosquamella Ragonot.
Acrobasis caryæ Grote.
Eucosma scudderiana Clemens.
Eucosma desertana Zeller.
Phlyctænia extricalis Guenée.
Apatela haustulifera Smith and Abbot.
Harrisina americana Guerin-Méneville.
Retinia sp. (?)

Prof. C. V. Riley records [1] *Perilampus platygaster* Say as a parasite of *Harrisina americana* in the State of Missouri.

A species of *Perilampus* was reared, according to the labels in the United States National Museum, by Mr. D. W. Coquillett from the cocoon of a *Chrysopa* at Los Angeles, Cal. Dr. Ashmead also reared

[1] Second Report on the Noxious and Beneficial Insects of Missouri, p. 87, 1870.

a species from *Chrysopa* at Utica, Miss., this record being the one referred to in his Monograph of the Chalcidoidea.

In a paper entitled "A list of the parasites known to attack North American Rhynchophora,"[1] Mr. W. D. Pierce records *Perilampus* as a parasite of the cotton boll weevil (*Anthonomus grandis* Boheman) in cotton squares in Louisiana. Mr. Pierce in a recent letter regarding this record states that it is open to question. A cotton square from which a weevil had emerged forms an excellent retreat for another insect that might be inclined to secrete itself in this manner. It may be that in this case a *Chrysopa* larva parasitized by *Perilampus* crawled into the square to pupate and from this the *Perilampus* emerged later. That *Chrysopa* is prone to do just this thing is a well-known fact. Dr. Howard described the chalcidoid parasite *Isodromus iceryæ* as a parasite of the scale *Icerya*. He later found that *Isodromus* was instead a parasite of *Chrysopa*, which in this instance had crawled beneath the *Icerya* scale, through which the *Isodromus* later emerged.

In 1897 Mr. W. F. Fiske reared a single specimen of *Perilampus hyalinus* from the cocoon of *Limnerium fugitivum* Say as a parasite of *Hyphantria*. This fact was recorded in his paper on the parasites of the American tent caterpillar,[2] and probably constitutes the first published record of *Perilampus* as a secondary parasite on Hymenoptera.

Quaintance and Brues in their study of the cotton bollworm[3] found this species to be a rather uncommon parasite of *Microplitis nigripennis* Ashmead, a braconid parasite of *Heliothis obsoleta* Fabricius in Arkansas and Texas.

Dr. L. O. Howard, in a paper entitled "The biology of the hymenopterous insects of the family Chalcididæ,"[4] makes the statement that *Perilampus* has been reared from Tachinidæ, but none of the details of the rearing was given. Dr. Howard, in a recent letter in regard to this, says that he is unable to find any record upon which this statement was based, but that he is of the opinion that it was reared from tachinid puparia in the office of the Entomologist at Washington prior to 1892. This is the first published record, so far as we are aware, of *Perilampus* as a parasite of Diptera.

Prof. M. H. Swenk[5] records having reared *Perilampus hyalinus* from a sarcophagid which in turn was reared from *Melanoplus bivittatus* Say.

---

[1] Journal of Economic Entomology, vol. 1, p. 383, 1908.
[2] New Hampshire College Agricultural Experiment Station, Technical Bulletin 6, p. 206, 1903.
[3] Bulletin 50, Bureau of Entomology, U. S. Department of Agriculture, p. 122, 1905.
[4] Proceedings of the U. S. National Museum, vol. 14, p. 574, 1892.
[5] Journal of Economic Entomology, vol. 4, p. 286, 1911.

EUROPEAN REARING RECORDS OF PERILAMPUS.[1]

Perilampus angustatus Nees.

This species was reared by Rondani [2] from the wood-boring larva of *Anobium molle*. Gaulle [3] records *angustatus* as a parasite of *Dryophilus pusillus*.

Perilampus auratus Panzer.

According to Gaulle,[3] this species has been reared from the crabronid wasps *Solenius rubicola* and *S. vagus* by Lichtenstein.

Perilampus levifrons Dalman.

Rondani [2] has reared *levifrons* from the larvæ of the tortricid *Coccyx buoliana* and also from the codling moth (*Carpocapsa pomonella* L.). Gaulle [3] gives an additional host in *Exocentris punctipennis*. Dour [4] mentions the first two records, crediting the first to Gouraud.

Perilampus micans Dalman.

This parasite was reared by Rondani [2] from the larvæ of *Lyctus canaliculatus* and *Hister picipes*.

Perilampus ruficornis Fabricius.

Gaulle [3] records this insect as a parasite of *Hylophila bicolorana*. Rondani [2] has reared it from the lepidopterous *Halias quercana*. Dalle Torre regards *violaceus* Fabricius as a synonym of this species.

Ratzeburg [5] refers to a *Perilampus* which he calls *violaceus* as follows: [6]

> Herr Reissig was so fortunate as to rear a female of this species. The host was not determined definitely, but it was without doubt a forest insect. On an oak leaf he found the dried remains of a tortricid larva. The parasitic larva had come out of this and had hung itself by a spun thread. The cocoon has the compact form of those of *Campoplex*, is two lines long, transparent (but nevertheless of close texture), dark brown, with a somewhat lighter band. The large opening through which the *Perilampus* had gnawed its way is at one end and appears as an irregularly torn circle.

There seems to be little doubt that Ratzeburg was incorrect in his surmise that this species was primary upon the tortricid. *Perilampus* of course does not spin a cocoon, or even a thread. The cocoon which he describes was almost certainly that of *Campoplex*, which he says it resembles, and with which his description agrees.

---

[1] The author is indebted to Dr. L. O. Howard for examining literature which was inaccessible.

[2] Bulletino della Società Entomologica Italiana, vol. 4, pp. 57–58, 1872; vol. 8, pp. 241–242, 1876.

[3] Catalogue systematique et biologiques des Hyménoptères de France, in La Feuilles des Jeunes Naturalistes.

[4] Catalogue synonimique des Hyménoptères de France, in Mémoires de Société Linnéene du Nord de la France.

[5] Ichneumonen der Forstinsekten, vol. 3, p. 221.

[6] Translation by the author.

This *Campoplex* was probably parasitic on the tortricid, and the *Perilampus* destroyed it as a secondary parasite.

There is almost certainly more than one species under the name *ruficornis*, as the records indicate that it has been reared from moths as a primary parasite, and from an ichneumonid as a secondary. That this would occur in a single species seems hardly probable in view of its highly specialized life cycle.

Perilampus italicus Fabricius.

Recorded by Gaulle [1] as a parasite of the sawfly *Athalia colibri*.

Of course there is always the possibility that the specimens recorded from Lepidoptera really came from tachinids or ichneumonids which transform within their host. It is difficult to understand how the *Perilampus* larva, being an external feeder for the greater part of its life, could feed and develop externally upon the pupa of an ectophagous lepidopteron, taking for granted that the mode of development is similar in all the species of the genus. It might, however, be able to do so upon a lepidopterous host which feeds within stems or galls, the *Perilampus* in this case being protected from injury.

EUROPEAN SPECIES OF PERILAMPUS REARED AT THE LABORATORY.

Perilampus cuprinus Förster.

In 1906 several individuals of *Perilampus cuprinus* were reared by Mr. Titus from puparia of imported tachinids parasitic upon the gipsy moth and brown-tail moth. Occasionally a few more were secured under similar circumstances, but never in numbers sufficient to indicate that the species was of any particular importance as a secondary parasite. Neither were there any records which indicated that any species of the genus was of more than incidental interest in connection with lepidopterous hosts.

The tachinids acting as hosts were not identified in every instance, but among those species attacking the gipsy moth are *Blepharipa scutellata* Robineau Desvoidy, *Compsilura concinnata* Meigen, and *Tricholyga grandis* Zetterstedt, and among the brown-tail moth parasites are *Pales pavida* Rondani and *Parexorista cheloniæ* Rondani. It is practically certain that all of the tachinids and probably some of the ichneumonids and braconids preying upon this host are liable to attack by *Perilampus*. It is also possible, but not proven, that it is at times an enemy of sarcophagids which usually and probably always attack pupæ which have died from other causes.

In no instance has the planidium of this species been seen but there is hardly a doubt that this stage exists and that in its essential

[1] Catalogue systematique et biologique des Hyménoptères de France, in La Feuilles des Jeunes Naturalistes.

characteristics it resembles the planidium of *P. hyalinus* and others described in the preceding pages. It is also probable that the later larval development is analogous to that of *P. hyalinus* and that the beginning of development of the pupa is the signal which stirs the planidium into activity.

Varichæta, as has been shown, hibernates as a pupa which has not begun to show the color or characteristics of the adult, and the *Perilampus* planidium remains dormant throughout the winter and feeds in the spring. Among the European tachinids known to act the part of host to *P. cuprinus, Compsilura, Tricholyga,* and *Pales* issue in the summer, much as do the summer-issuing hymenopterous parasites of the fall webworm, and *P. cuprinus* completes its transformations and hibernates as an adult without leaving the puparium. *Blepharipa,* unlike *Varichæta,* develops imaginal characters in the fall and is, so far as external evidences indicate, ready to emerge before winter. *Perilampus* as a parasite of *Blepharipa* acts exactly as it would had its host actually emerged in the fall, and hibernates as an adult within the puparium. *Parexorista* hibernates like *Varichæta,* and if the parallel between *P. hyalinus* and *P. cuprinus* is as close as is believed, the planidium hibernates as such and becomes active when its host begins to develop in the spring.

Perilampus inimicus Crawford.

A relatively small number of this species, recently described in Part II of this bulletin, was reared in 1908 from the cocoons of *Apanteles fulvipes* var. *japonica* Ashm., imported that year from Japan as a parasite of the gipsy moth. It has not been reared as a parasite of Japanese tachinids, but it may well be that it resembles *P. cuprinus* in habits, and that it will be reared when larger importations of tachinids from Japan have been made.

The specimens reared issued in the late summer, coincidently with the emergence of the other more common chalcidoid parasites of the same host.

Perilampus sp.

Another species of *Perilampus,* as yet undetermined, has been reared from the cocoons of a European *Apanteles* parasitic upon the young brown-tail moth caterpillars. The circumstances are interesting and suggestive but the incident will be discussed more at length in another connection.

RÉSUMÉ OF HOST RELATIONS OF THE GENUS.

Species of the genus *Perilampus* have been reared [1] from insects belonging to five different orders, Hymenoptera, Diptera, Lepi-

[1] This is according to the published records, although some of them are almost certainly incorrect.

doptera, Coleoptera, and Neuroptera, in Europe, Japan, and America. Table III shows the number of each group from which *Perilampus* has been reared in those regions where the gipsy moth is found:

TABLE III.—*Classification and distribution of the known hosts of the genus Perilampus.*

	America.	Europe.	Japan.	Total.
Hymenoptera parasitica	8	2	1	11
Hymenoptera phytophaga	.....	1	.....	1
Hymenoptera aculeata	.....	2	.....	2
Diptera (Tachinidæ)	4	5	.....	9
Lepidoptera	8	5	.....	13
Coleoptera	1 (?)	4	.....	5
Neuroptera	1	.....	.....	1
Total	22	19	1	42

THE ECONOMIC ASPECTS.

In 1906 Mr. E. S. G. Titus, at that time in charge of the Gipsy Moth Parasite Laboratory, reared a few cocoons of *Apanteles vimenetorum* Wesmael [1] from caterpillars of the brown-tail moth which had been imported in the hibernating nests. From them there emerged a very few specimens of a species of *Mesochorus*, different from any known American secondary upon *Apanteles* and apparently but not certainly European. The circumstances under which the *Apanteles* were reared were not such as absolutely to protect them from the attack of the native hyperparasites, but there was good reason to believe that the *Mesochorus*, as well as the *Apanteles*, had attacked the very small caterpillars of the brown-tail moth in Europe the fall before. This was the first instance encountered in the course of the work of parasite introduction in which a secondary parasite was known or suspected to attack a primary parasite before the death of the primary host.

In 1907 this record was confirmed, and it was demonstrated beyond possibility of error that there were some secondary parasites which had this habit. The fact was of the greatest significance, since it was one of the fixed policies of the laboratory to introduce the primary parasites of the gipsy and brown-tail moths and to exclude the secondary. It had been supposed that this could be accomplished by importing the living caterpillars and pupæ of the gipsy and brown-tail moths and rearing the parasites. The fact that the primaries might be attacked before the death of their host altered the situation materially and made the strictest supervision of imported material necessary in order to meet the ideal which had been set.

That the relative importance of hyperparasitism has diminished rather than increased as a result of a better understanding of the

[1] As determined by Schmiedeknecht.

subject affects the matter scarcely at all. We know now that the primary parasites of the gipsy and brown-tail moths, if they become established, will be subjected to the attack of native hyperparasites to a varying degree in accordance with the closeness of their resemblance in natural affinities and habits to American species, but there are among them a few which are so different from any American species as to make it probable that they will largely escape undue parasitism in America, much as the gipsy and brown-tail moths have themselves escaped. This does not lessen the force of the original contention at all materially. It has simply served to separate the secondary parasites into bad, worse, and worst, and has left them as a group with about the same degree of odium attached as before.

The separation of the several secondary parasites into groups in accordance with their capabilities for evil has not always been easy. As with the primary parasites, the importance of which can not be inferred from the numbers which chance to be reared from the imported material, the secondary parasites, which are the least frequently encountered, may easily be the most to be feared.

Perilampus has never been abundant as a parasite of tachinids in any of the imported material. So far as is directly indicated by our notes and breeding records there is nothing in its life or habits which would separate it from the minor and inconsequential secondary parasites, of which there are many species.

These opinions, formerly held, have been changed as a result of the investigations into the life and habits of the native *Perilampus hyalinus*. It was not known or suspected, in spite of the considerable study which the fall webworm has received at various times and by various entomologists, that this secondary was of any more interest or importance than any other, but it is now evident that species of this genus may become of the greatest importance as hyperparasites. It is further indicated as a direct result of these studies that the different species of *Perilampus* are likely to concentrate their attack upon the parasites of some particular primary host instead of scattering their attack upon all of the very numerous species of hymenopterous and dipterous parasites suitable in other respects. Thus *Perilampus hyalinus* appears to be particularly a parasite of the parasites of the fall webworm. It is possible that it will never attack the parasites of the gipsy moth or the brown-tail moth. *Perilampus cuprinus*, for all that is positively known to the contrary, may similarly concentrate its attack upon the parasites of the gipsy moth and the brown-tail moth and might become a factor of as much importance in the natural control of these insects as *Perilampus hyalinus* undoubtedly is in the control of *Varichæta*.

It is not probable, but it is conceivable, that the establishment of *P. cuprinus* in America might make all the difference between success and failure of the whole work of parasite introduction, in so far as the gipsy moth is concerned, because, in the first place, *Blepharipa scutellata* is one of the most important parasites of the gipsy moth and the success or failure attending the attempts to introduce it into America might easily tip the scale one way or the other, and *Perilampus*, so far as known, is the most important parasite of *Blepharipa* and might in a similar manner determine whether or not its host reached the necessary state of efficiency.

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 5 cents per copy

TECHNICAL SERIES NO. 19, PART V.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

V. EXPERIMENTAL PARASITISM:

A STUDY OF THE BIOLOGY OF LIMNERIUM VALIDUM (CRESSON).

By P. H. TIMBERLAKE, A. M.,

Agent and Expert, Gipsy Moth Parasite Laboratory.

ISSUED MAY 29, 1912.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *in charge of library.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, Harry S. Smith,[1] P. H. Timberlake,[2] C. W. Collins, H. E. Smith, F. H. Mosher, J. N. Summers, Chas. W. Minott, C. W. Stockwell, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants.*

---

[1] Transferred to cereal and forage insect investigations.
[2] Transferred to citrus fruit insect investigations.

CONTENTS.

	Page.
Introduction	71
Experiments	72
General methods of experimentation	72
Behavior of *Limnerium validum* (Cresson) in confinement	73
Limnerium validum as a parasite of *Euproctis chrysorrhœa* (Linnaeus)	73
First experiment	74
Second experiment	74
Amœbocytosis as a protective reaction of the host	75
Adaptation of parasite to host	76
Further experiments with *Euproctis chrysorrhœa*	77
Limnerium validum as a parasite of *Malacosoma americana* (Fabricius)	78
Results of experiments as determined by dissection	78
Emergence of adults of *Limnerium* from reproduction	79
Length of the stages in the life history of *Limnerium*	80
A possibly normal parasite of *Malacosoma*	80
Limnerium validum as a parasite of *Notolophus antiquus* (Linnaeus)	81
Limnerium validum as a parasite of *Porthetria dispar* (Linnaeus)	82
Experiments with other hosts	83
Notes on development and anatomy of the larva	83
The egg	83
The first-stage larva	84
Description of the newly hatched larva	84
Function of the tail appendage	85
Appearance of older larvæ	85
Notes on the anatomy of the larva	86
The second-stage larva	87
The third-stage larva	87
Description of the full-grown larva	87
Feeding habits of the imprisoned larva	88
Respiration of the larva in the third stage	89
The cocoon	90
Results of the dissections of *Hyphantria* during the fall of 1910	90
General summary	91
Bibliography	92

ILLUSTRATIONS.

Page.

FIG. 32. *Limnerium validum:* Adult female, abdomen of male, metascutum, cocoon 72
33. *Limnerium validum:* Egg 83
34. *Limnerium validum:* Eclosion of larva 83
35. *Limnerium validum:* First-stage larva, newly hatched 84
36. *Limnerium validum:* First-stage larva of large size, showing silk glands and nervous system 85
37. *Limnerium validum:* Mouthparts of first-stage larva 86
38. *Limnerium validum:* Second-stage larva 87
39. *Limnerium validum:* Mouthparts of second-stage larva 87
40. *Limnerium validum:* Third-stage larva 88
41. *Limnerium validum:* Anterior view of head of third-stage larva, showing mouthparts 88

U. S. D. A., B. E. Tech. Ser. 19, Pt. V. Issued May 29, 1912.

TECHNICAL RESULTS FROM THE GIPSY MOTH PARASITE LABORATORY.

V. Experimental Parasitism: A Study of the Biology of Limnerium Validum (Cresson).

By P. H. Timberlake, A. M.,
Agent and Expert, Gipsy Moth Parasite Laboratory.

INTRODUCTION.

The biology of none of our American parasitic Hymenoptera is too well known to demand an apology for the appearance of this article, and it is the hope of the author that the results of the studies here set forth will call to the attention of our professional and amateur entomologists this exceedingly rich but almost untouched field for investigation. A little of the ecology, especially of the host relationship, of many of our parasites has been recorded, but the various and interesting adaptations in the larval structure and habits of our different species are almost unknown.

In connection with the practical work at the Gipsy Moth Parasite Laboratory of importing and liberating parasites of the gipsy and brown-tail moths, considerable attention is paid to the habits and biology not only of the imported parasites, but also of our native parasites of caterpillars that resemble the gipsy moth or brown-tail moth in habits or destructiveness. In this way considerable knowledge has accumulated which, besides its intrinsic and theoretical value, has been useful in perfecting the methods of handling the imported species and in showing which of our American species, if any, may be expected to become contributing factors in the control of these pests.

It was especially with this latter idea in mind that in the spring of 1910 a series of experiments was undertaken to work out the biology of our native *Limnerium validum* (Cresson) (fig. 32) and its behavior toward unusual hosts. The experiments grew out of a successful attempt to foster oviposition on small brown-tail moth caterpillars (*Euproctis chrysorrhœa* Linnaeus), which yielded such unexpected complications that the work was continued on other hosts as they became available in the course of the spring.

Limnerium validum proved to be an excellent subject for experimentation for several reasons, but chiefly on account of its docility in

confinement and the readiness with which it attacks any suitable species of caterpillar and because the heavily chitinized chorion of the egg is remarkably durable. This last fact was an advantage in determining the number of eggs deposited in a caterpillar, even when considerable time had elapsed after the hatching of the larva. Fortunately for the success of the experiments an abundance of adults of this species was at hand, reared from cocoons obtained the preceding fall from its usual host, *Hypantria cunea* (Drury).

This *Limnerium* is one of the hymenopterous parasites affecting the fall webworm (*Hyphantria cunea*); and although not so important as *Meteorus* and *Apanteles*, it is frequently found. In the northern States it emerges from the fall webworm and spins its cocoon mostly during the month of September. Unlike *Limnerium pilosulum* (Provancher), another species common on *Hyphantria*, it hibernates in its cocoon until late the following spring or summer, and consequently it has been considered to have only a single generation a year. Farther south, however, as pointed out by Dr. L. O. Howard (1897) in his bulletin on the white-marked tussock-moth (*Hemerocampa leucostigma* Smith and Abbot), of which it is an unimportant parasite, it probably hibernates as an adult, as its empty cocoons were found associated with "spun-up" larvæ of the *Hemerocampa* in the middle of December. Dr. Howard also records rearing the adult as early as the middle of July, so that in the vicinity of Washington, D. C., two generations, if not more, occur annually. Besides its favored host, *Hyphantria cunea*, and the *Hemerocampa*, it probably attacks other caterpillars, but so far as the author is aware no other rearings have been recorded.

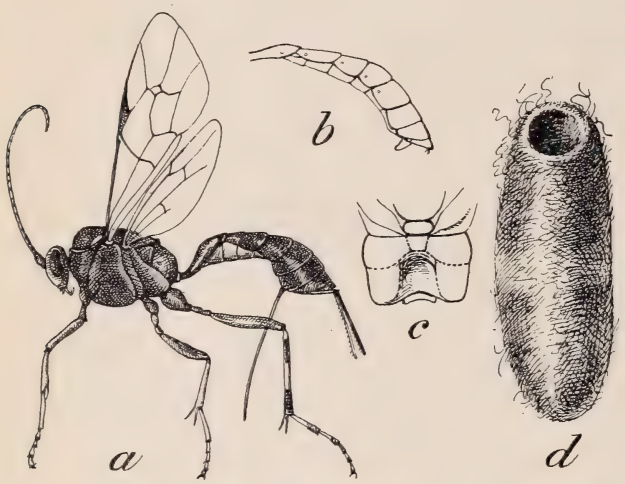

FIG. 32.—*Limnerium validum*: *a*, Adult female, side view; *b*, abdomen of male; *c*, metascutum from above; *d*, cocoon. Enlarged. (*a*, *b*, *d*, Redrawn from Howard; *c*, original.)

EXPERIMENTS.

GENERAL METHODS OF EXPERIMENTATION.

In most of the experiments undertaken with *Limnerium validum* the parasites and caterpillars were confined together in large glass cylinders covered at the top with cheesecloth, and resting on cloth-covered frames. When it was desirable, however, to have a large

number of caterpillars, a small, flat tray was used, wire screened on the bottom and covered with glass. A small hole in the side of the tray was found useful in introducing fresh foliage sprayed with sweetened water, as food for the caterpillars and parasites. In the first experiments several females of the *Limnerium* were confined with a limited number of caterpillars, but later, when it was discovered how readily the parasites attacked the hosts, the number of the latter was proportionately increased. Dissection of the caterpillars was chiefly relied upon in working out the results of each experiment.

BEHAVIOR OF LIMNERIUM VALIDUM (CRESSON) IN CONFINEMENT.

This species did not become overrestless in confinement, and hardly betrayed the excitement that some parasites are said to do when in proximity to their hosts. This tranquility may possibly be explained by the fact that the *Limnerium* was always confined with species of caterpillars that do not naturally serve it as hosts, and it might have been stimulated, perhaps, to greater activity by fall webworms. The females, however, readily oviposited in 4 of the 6 species of caterpillars with which they were confined. The postero-dorsal part of the host was usually chosen as the most suitable point for attack, and there seems to be a more or less well-developed instinct in this as well as other parasites to keep away from the head of the caterpillar in ovipositing. This instinct is not so necessary for large, strong parasites like *Limnerium validum*, but may be of great advantage to small, weak species like *Meteorus* or *Apanteles*. These frequently attack caterpillars that are many times their size, and might easily fall a victim to one vicious sweep of the host's head, or become so daubed up by juices exuding from the mouth of the excited caterpillar that they could not escape. As circumstantial evidence of the existence of this instinct, comparatively few eggs were found near the head in dissected caterpillars, and by far the greater number was found in the posterior half of the body. A favored site for them was in the extreme tip of the postero-dorsal part of the body cavity just beneath the integument.

The males of *Limnerium* were slightly more active than the females in running about the cage, but they paid no attention to the caterpillars, and but little attention to the females. None was ever seen attempting to mate.

LIMNERIUM VALIDUM AS A PARASITE OF EUPROCTIS CHRYSORRHŒA (LINNAEUS).

Three experiments were undertaken during February and March, 1910, to determine whether *Limnerium validum* would successfully attack brown-tail caterpillars, and to collect data, if possible, on the early stages.

FIRST EXPERIMENT.

In the first experiment, on February 2, 5 females of *Limnerium* were confined in a small glass cylinder with 10 active brown-tail caterpillars about 8 mm. long. The experiment was closed on February 15, at which time the last of the caterpillars died. Nine of the caterpillars were carefully dissected and a count made of the easily discovered eggs and larvæ of *Limnerium*. The largest number found in one caterpillar was 23 eggs and 11 larvæ with the empty eggshells, dissected from one that died on February 11. The smallest number was 4 eggs and 5 larvæ taken from a dead caterpillar on February 15. One hundred and forty-six eggs and 72 larvæ were found in all, making a total of 218 eggs deposited by the 5 females in the course of the 4 to 6 days that they remained alive, or an average of nearly 44 eggs for each female, and about 24 to each caterpillar.

With this unusual number of eggs and larvæ present, it is no wonder that the caterpillars failed to survive. As the caterpillars in every case died before the larvæ had grown to any appreciable extent and even before all the eggs had hatched, it is not probable that they were killed by the feeding of the parasites. It is much more probable that they succumbed to the mechanical irritation produced by so many eggs and larvæ, which not only may have caused a violent disturbance or pathological condition of the body tissues, but also tended to keep them from feeding.

SECOND EXPERIMENT.

A second experiment was started on February 5, with 5 females and 13 active brown-tail caterpillars. By February 9, all the parasites were dead, and 3 caterpillars were found dead on the 11th and 5 more on the 19th. In the 8 dead caterpillars 61 unhatched and 5 hatched eggs were found, but only 1 larva, which had grown to be about five times the size of newly hatched larvæ, although still in the first stage. About 8 eggs, on an average, were thus found in each caterpillar, and they were undoubtedly at least a strong contributing factor in causing the death of the latter.

Three of the 5 living caterpillars were dissected on February 19 and the remaining two on March 4. In these 5 caterpillars only 1 unhatched egg and 12 eggshells with only 4 larvæ were found. This, on an average, is only 2 or 3 to each caterpillar, for although 1 had been victimized 8 times, 1 had escaped altogether. Only 4 larvæ were found, and of these 3 had died shortly after hatching before growing to any extent, whereas 1 had managed to live and increase in size about five times. In the 13 caterpillars dissected, 72 unhatched eggs, 17 hatched eggs, and 5 larvæ were found, or nearly 7 to a caterpillar and 18 for each female *Limnerium*.

AMŒBOCYTOSIS AS A PROTECTIVE REACTION OF THE HOST.

The remarkable fact in the array of figures just given is the disparity between the number of eggshells or cast choria found and the number of larvæ. The latter were large enough so that they could not have been overlooked, and the only explanation is that they had been killed by the host and absorbed by the blood tissues, or destroyed, in other words, by amœbocytosis. The chitinous choria, on the other hand, escaped unharmed. In the preceding experiment, in one of the dead caterpillars dissected on February 15 the dead larvæ and some of the eggs and eggshells were found inclosed in a firm, thick, homogeneous-appearing, transparent capsule of tissue. The significance of this was not realized at that time, but when on February 19 the same phenomenon was noticed in the dissection of living caterpillars, the mystery of the missing larvæ was explained, for when the capsule was stained in methyl green and mounted in glycerin, it was resolved under the high power of the microscope into innumerable, densely packed, minute, roundish and spindle-shaped cells. These were undoubtedly blood-tissue cells or amœbocytes, and whereas they were not true phagocytes, yet their function must have been to break down and absorb the tissues of the parasites, for within the capsules larvæ were found in several stages of dissolution.

Later experiments with the same and other hosts, such as *Malacosoma* and *Notolophus*, brought to light the fact that this amœbocytic reaction takes place regularly when the *Limnerium* occurs in these hosts to which it seems to be unaccustomed and unadapted. In most cases it was found that the parasite was able to hatch from its egg, but that it perished generally soon afterwards before growing to any extent. Many times the larva was found to have disappeared entirely through the action of the amœbocytes, yet the story of its death and dissolution was told by the encapsulated remains of the much more resistant eggshell. Whether the amœbocytes gathered around and killed the living larvæ and eggs or attacked only parasites that had been killed by some other factor was not certainly determined; but the former supposition is probably correct, as unhatched eggs containing embryos in different stages of dissolution were found sometimes inclosed in sheaths of these cells. In one instance, also, a larva that had grown to be about six times the size of newly hatched larvæ, was found entirely inclosed except for its head in a characteristic sheath. This larva was probably living when its host was killed for dissection, or at least, judging from its fresh and uninjured condition, it could not have been dead for more than a few hours.

An extended series of dissections of *Hyphantria cunea*, on the other hand, made by J. D. Tothill during the fall of 1910, showed that the

larvæ of *Limnerium* are free from the slightest trace of amœbocytic attack when occurring in their natural host.

Other phases of this so-called "phagocytosis" have been studied by several European investigators, especially by Cuenot (1896), Janet (1906, 1907), and Pantel (1910). The latter author has given a summary of those cases of amœbocytosis that were known to him in his excellent "*Recherches sur les Diptères a Larves Entomobies.*" He concludes that this defensive reaction of the host is aroused not only by bacterial infection but also by sick or dead parasitic larvæ and by molt skins, and states that free and healthy larvæ are regularly exempt.

The only cases of sick larvæ that Pantel seems to have observed are larvæ of Tachinidæ that have fallen accidentally from their breathing holes, generally during the molting of the host. Such larvæ do not affix themselves anew, but wander about in the body cavity of the host until overcome by suffocation. Pantel further observes that the anal sheaths of such larvæ begin to turn brown and become inclosed by a great number of amœbocytes, which finally almost completely cover the larva.

In the case of dead larvæ which have perished in the struggle for the possession of the host, Pantel observes that their bodies only exceptionally become incapsulated by amœbocytes. The molt skins, on the other hand, he furthermore states, are attacked, not always, but most frequently by amœbocytes.

The similar action of amœbocytes in breaking down the wing muscles of queen ants has been described by Janet (1906, 1907). The muscles are not devoured in small fragments by phagocytes, but are disintegrated gradually and absorbed by amœbocytes, which creep in among the fibrillæ in large numbers.

We have seemingly in this amœbocytic reaction a manifestation of the protective faculty of the host in guarding against the attack of entoparasites. As shown by Pantel (1910) and confirmed by our own observations of various species of parasitic Diptera and Hymenoptera, normal or adapted parasitic larvæ, when healthy, rarely if ever arouse this defensive reaction, or, in other possibly more correct words, they are able to repel the amœbocytes by some curious adaptation. Unadapted parasites, on the contrary, being unable to repel the amœbocytes, may regularly succumb to their agency. The instinct of parasites under ordinary conditions well fits them for choosing their accustomed hosts, but in the millions of instances where this instinct comes into play, an egg may be placed occasionally in an unsuitable host. In such cases the resulting larva seems to be doomed to a lingering death, and its tissues are absorbed by the amœbocytes with no ultimate detriment to the host.

ADAPTATION OF PARASITE TO HOST.

The phenomenon of amœbocytosis, on the other hand, brings up the question, Why do not all parasites suffer the same fate, and what

constitutes adaptation? We begin here to sink deep into the quagmire of speculation and doubt. We may say that the parasitic larva is so similar to the host in its effluvia or physical being, that its presence is not felt or resented, and that it bears much the same relation to the host that the fetus within the uterus does to the mammalian mother; or we may conclude that it secretes substances into the blood which paralyze the protective reactions of the host. We are more inclined to accept the latter view, for we have observed several phenomena in the course of other dissections which are difficult to explain except by a secretion hypothesis.

In dissecting various parasitized insects we have often noticed pathological changes in the body tissues, and especially that the flaky fat bodies are often converted into a number of comparatively gigantic, globular cells which are unattached and float freely about in the blood of the insect. In dissecting brown-tail moth caterpillars imported from Europe we have seen small first-stage larvæ of *Meteorus* exert a strange and fatal influence over the larvæ of *Zygobothria nidicola* Fallen, when occurring together in the same host. The larvæ of *Meteorus* live free in the body cavity of the host at the extreme posterior end of the body on the dorsal side, whereas the maggot of *Zygobothria* is normally found encysted in the wall of the crop or œsophagus. In the few cases in which both were found in the same caterpillar, the maggot of *Zygobothria* had left its cyst in the crop, and was either wandering about in the body cavity of the host or had already died. How can we explain this strange and untimely reaction of the maggot, unless we consider that it had been stimulated to activity by some unusual substance in the blood tissues of the host, either secreted by the larvæ of *Meteorus*, or by the host itself in reaction thereto?

FURTHER EXPERIMENTS WITH EUPROCTIS CHRYSORRHŒA.

A third experiment was started on February 15 with about 100 brown-tail moth caterpillars that had been feeding for 20 days and were consequently about 10 mm. long. These caterpillars were placed in a small tray, and 15 females of *Limnerium* were confined with them between the 15th and 27th of February, fresh females being added as the first ones died.

Dissection of living caterpillars was undertaken on the 4th of March and continued on the 14th. Thirty-four caterpillars in all were dissected and 15 were found to be parasitized by *Limnerium*. Not more than 2 larvæ or eggs were found, on an average, in a single caterpillar, and the larvæ were in most cases dead. Only one larva, in fact, had obtained any size, and it was only about six times as large as the newly hatched larvæ. Although incrusted with a capsule of amœbocytes it may have been still alive, but could not have survived

much longer. All the other larvæ that were found were newly hatched, or had been killed soon after hatching, and were commonly inclosed in a sheath of amœbocytes.

The rest of the caterpillars were kept alive as long as possible in the hope that one or two of the *Limnerium* might be able to pass through their transformations, but none was reared. The experiment therefore furnished data similar to those obtained in the preceding experiments, and conclusively confirmed the belief that *Limnerium validum* is unable to live as a parasite within brown-tail moth caterpillars.

LIMNERIUM VALIDUM AS A PARASITE OF MALACOSOMA AMERICANA (FABRICIUS).

On April 20 an experiment was started with *Limnerium validum* as a parasite of the common tent caterpillar (*Malacosoma americana* Fabricius). Three females were confined in a large, flat, tanglefooted tray, with three nestfuls of caterpillars, mostly in the second stage, collected in the open at Melrose Highlands, Mass. A fourth nest was added on the 21st to insure an abundance of caterpillars for the *Limnerium* to attack. By the 26th the *Limnerium* had all died, but 2 more females were placed in the tray on the 28th. Many of the caterpillars at that time were passing into the third stage.

RESULTS OF EXPERIMENTS AS DETERMINED BY DISSECTION.

On May 3 dissections were made of 6 second-stage and 11 third-stage caterpillars, of which all of the former and 9 of the latter were found to be parasitized. The results of the dissections are given in Table I.

TABLE I.—*Results of dissections of caterpillars of Malacosoma americana parasitized by Limnerium validum.*

Stage of host.	Number of eggs laid.	Number of eggshells found.	Number of larvæ found.	Condition of larvæ.	Other data.
Third	1	1	1	Living	
Do	1	1	1	do	
Do	3	3	2	1 living	Dead larva only partially eclosed.
				1 dead	1 larva already destroyed.
Do	1	1	1	Living	
Second	1				1 dead egg covered with amœbocytes.
Do	1	1	1	Living	
Do	1		1	do	Eggshell not found.
Do	1	1	1	do	
Third	2	2	1	do	1 larva already destroyed.
Second	2	1	1	do	1 dead egg covered with amœbocytes.
Do	1	1	1	do	
Third	1	1	1	do	
Do					Host not parasitized.
Do	1		1	Living	Eggshell not found.
Do	1	1	1	do	
Do					Host not parasitized.
Do	1	1	1	Living	
Total (17 hosts)	19	15	15		

According to the dissections 19 eggs were deposited in the 17 caterpillars, distributed as follows: One caterpillar was parasitized three times, 2 twice, 12 once, and 2 escaped parasitism altogether. Of the 19 eggs deposited, 2 failed to hatch and became covered with amœbocytes, as did also the eggshells except in one doubtful instance, and in case of a third the embryo or larva was killed during the process of eclosion, becoming also densely encapsulated with amœbocytes. Two other larvæ were killed after hatching, and were entirely destroyed by the action of the amœbocytes, but their former presence was revealed by the empty eggshells. The remaining 14 larvæ were in a living and apparently healthy condition. Some were recently hatched, but others had grown to an appreciable extent. They lay free in the body cavity of the host, generally in the posterior half of the body, either above or below the digestive tube, and with the head directed caudad in respect to the host.

On the 7th of May, 5 caterpillars in the fourth stage were dissected, and in 2 of them was found a living first-stage larva; on the 11th, 10 more caterpillars were dissected, but none was parasitized; again on the 19th 2 caterpillars out of 10 in the fourth and fifth stages were found to be parasitized. One contained a living, first-stage larva of *Limnerium*, the other a living larva in the second stage, each host being about 20 mm. long.

EMERGENCE OF ADULTS OF LIMNERIUM FROM REPRODUCTION.

On the 21st of May, 2 unspun, full-grown larvæ of *Limnerium* were discovered in the tray, and between that time and the 1st of June, 29 in all were found, 6 of which died before spinning cocoons. The rest spun perfect cocoons, and 6 passed through their transformations to the imagos, in every case males, from June 7 to June 14. The remaining 17 cocoons remained unissued up to December 13, when they were cut open and examined. All were found to contain dead larvæ, some perfectly dry and shriveled, although 4 seemed only recently dead, as they were still plump although much discolored.

In all cases in this experiment where remains of the host were found associated with the larva or cocoon, the *Limnerium* issued from half-grown caterpillars, which were mostly in the fourth stage, although a few appeared to be small and stunted specimens of the fifth stage. On May 28 the remains of a host were examined. This caterpillar was killed by the parasite when about 25 mm. long, while still in the fourth stage. It had a large, round hole in the integument on the ventral side, just back of the head, through which the larva escaped, after destroying all of the internal organs. The integument inside was left perfectly dry and bare, except for a small amount of broken-down tissue at the extreme posterior tip of the body.

LENGTH OF THE STAGES IN THE LIFE HISTORY OF LIMNERIUM.

From this and the preceding experiments we may estimate that the duration of the embryonic development of *Limnerium validum*, or the time from oviposition to the hatching of the egg, is about 6 to 8 days; that the larval developmental period lasts for about 24 to 33 days; and that the pupal period, or, more exactly, the time from the spinning of the cocoon to the eclosion of the adult, is about 13 to 22 days, or much longer. The length of the larval period within the cocoon before pupation was not determined, but, judging from the cocoons examined on December 13, it may be extended several months. The minimum time from egg to imago is thus about 7 weeks, or 50 days, whereas the maximum time to the eclosion of the adult may be many months, due to quiescence within the cocoon. This species hitherto has been considered to have a single generation a year, but this last experiment seems to indicate that under certain conditions at least it is able to pass through two generations annually. Under normal conditions, however, there is much doubt whether more than one generation actually occurs in the Northern States.

A POSSIBLY NORMAL PARASITE OF MALACOSOMA.

This experiment shows that *Limnerium validum* is a possibly normal parasite of the tent caterpillar, although it has never been found attacking that species in the field. The reason for this is obvious: The tent caterpillars hatch early in the spring, long before the *Limnerium* leaves its cocoon, and therefore are not in season for this parasite. From the fact, however, that nearly one-half of the caterpillars dissected in this experiment were found to be parasitized, and that comparatively few were killed by *Limnerium*, we may conclude that *Limnerium validum* is only partially adapted to this host. In the dissecting work only 5 dead larvæ or eggs were discovered, but many more without much doubt succumbed to the defensive reactions of the host. In the 42 caterpillars dissected, 23 eggs or larvæ were found, and 29 other larvæ were successful in passing through their larval development, making a total of only 52 parasites that came under observation. If the 5 females used in this experiment oviposited as freely, however, as those in the preceding experiments, and there is no reason to believe otherwise, some 100 to 200 eggs or even more were probably laid. Taking 100 as a conservative estimate, and with due allowance for the destruction wrought by the dissections, we may thus figure on a mortality of at least about 37 per cent. The cast eggshells were almost invariably found thickly ensheathed with amœbocytes, and the function of the latter was without doubt the same as in the case of the brown-tail moth caterpillars, to disintegrate if not to kill the young larvæ. In the present instance,

however, a few of the larvæ were able to withstand the action of the amœbocytes and reach maturity. This immunity of the few is of theoretical interest, as it would furnish a basis under proper conditions for the evolutionary development of complete host relationship. It is not difficult to conceive that this parasite in the course of not many generations might adapt itself so as to insure a minimum mortality, and thus become an effective enemy of the tent caterpillar.

LIMNERIUM VALIDUM AS A PARASITE OF NOTOLOPHUS ANTIQUUS (LINNAEUS).

One of the most interesting of the experiments was started May 9, 1910, with the rusty vaporer moth (*Notolophus antiquus* Linnaeus) as the host. One unfertilized female *Limnerium* was confined with 25 small, third-stage caterpillars. The female remained alive for 12 days and oviposited freely in the caterpillars.

Dissection work was commenced on June 17 and was continued at intervals until June 30. In all, 10 caterpillars, 1 pupa, and 7 moths were dissected. In the 10 caterpillars, a total of 40 eggs and eggshells was found, and 8 larvæ which were all dead; in the 1 pupa, 1 eggshell was found; and in the 7 moths, a total of 16 dead eggs and eggshells was discovered, making a total of 57 eggs laid by the single female in only 18 of the hosts. The results of the dissections are given more in detail in Table II.

This experiment proved conclusively that this parasite is not at all adapted to live at the expense of *Notolophus*. The larvæ, even if they were able to hatch, were killed by the host soon afterward, and at least 6 of the eggs were unable to hatch. Two other eggs were found with the dead larva only partially out of the shell. The larvæ in most cases were entirely destroyed by the host, so that all trace of them was lost, except for the cast eggshell, yet a few resisted total disintegration for a long period. The body tissues of the latter, however, were broken down, so that nothing was left but the integument. The eggshells, or dead eggs with the embryo inside, resisted destruction, on the other hand, to a remarkable degree, and were found practically unharmed for a month or even longer after they were laid, not only in the body cavity of the caterpillar and pupa but even in that of the adult moth, and invariably well incased in a sheath of amœbocytes. The eggshell in the single pupa dissected was found adhering to the ovarian tubules of the host; in the case of the moths, the eggs or shells were found many times just beneath the integument of the abdomen, or among the ovarian tubules. One female moth, which was in perfect condition and in no way inconvenienced, carried 6 of these eggshells.

TABLE II.—*Results of dissections of caterpillars and later stages of Notolophus antiquus parasitized by Limnerium validum.*

Date of dissection.	Stage and sex of host.	Number of eggs laid.	Number of unhatched eggs.	Number of egg-shells.	Number of larvæ.	Remarks.
May 17	Fourth-stage caterpillar.	2	2	.....	.....	Embryos not noticed within eggs.
Do	do	5	5	.....	.....	Do.
May 30	Fifth-stage caterpillar	3	.....	3	.....	No trace of larvæ.
Do	do	2	.....	2	2	Larvæ much broken down.
June 14	Sixth-stage caterpillar	2	.....	2	1	Larva killed before complete eclosion.
Do	Male moth	1	.....	1	.....	No trace of larva.
June 15	do	1	1	.....	.....	Egg contained dead embryo.
Do	Female pupa	1	.....	1	.....	Shell among egg tubes of host.
June 17	Sixth-stage caterpillar	7	2	5	1	Larva broken down. Host dead.
June 18	Male moth	1	.....	1	.....	No trace of larva.
June 20	Fifth-stage caterpillar	8	.....	8	1	Larva killed before complete eclosion. Host dead.
Do	do	.....	.....	.....	.....	Host dead, not parasitized.
Do	do	6	.....	6	2	Larvæ broken down; killed soon after eclosion. Host dead.
Do	Female moth	6	.....	6	.....	No trace of larvæ.
June 30	do	1	1	.....	.....	Egg contained dead embryo.
Do	do	5	2	3	.....	Two eggs contained dead embryos.
Do	Male moth	1	.....	1	.....	No trace of larva.
Do	Sixth-stage caterpillar	5	.....	5	1	Larva all destroyed except skin.
	Total	57	13	44	8	

LIMNERIUM VALIDUM AS A PARASITE OF PORTHETRIA DISPAR (LINNAEUS).

Two experiments were undertaken to determine whether this species of *Limnerium* can parasitize successfully the caterpillars of the gipsy math (*Porthetria dispar* Linnaeus). Both were, unfortunately, unsatisfactory in that the caterpillars were subject to disease and soon died in confinement. The second experiment only gave any results at all, and was started June 10, when 1 female *Limnerium* was confined with 20 caterpillars in the third and fourth stages, collected at Melrose Highlands, Mass.

On June 17 the female *Limnerium* was dead, and 19 of the caterpillars had succumbed to disease. These dead caterpillars were carefully dissected, and in 4 of them were found 18 eggs of *Limnerium*, occurring 2, 3, 5, and 8 in number, respectively. The eggs were all unhatched, the embryos undeveloped, and in some of the eggs the contents appeared to be broken down, such eggs being undoubtedly dead. Whether they had died through contact with dead and diseased tissues of the caterpillars or had been killed previously by some reaction of the host is not clear. In experiments with brown-tail moth caterpillars earlier in the season, living eggs and even larvæ were found within dead hosts; but in that case the caterpillars had not died from disease, but were killed by superparasitism.

On the 21st of June, 6 more of the caterpillars had died. They were dissected, and in one 5 eggs of *Limnerium* were found still unhatched. By June 31 the remaining 5 caterpillars had succumbed

to disease, and the experiment was closed without any conclusive evidence being gained, although the inference may be drawn that *Limnerium validum* is not adapted to the gipsy moth.

EXPERIMENTS WITH OTHER HOSTS.

Several experiments were also started with caterpillars of the common tussock moth (*Hemerocampa leucostigma* Smith and Abbot) and of the mourning-cloak butterfly (*Euvanessa antiopa* Linnaeus), but for various reasons they furnish no satisfactory evidence to show whether these hosts can be parasitized successfully by *Limnerium validum*. It is rather unfortunate that the experiment with the *Hemerocampa* did not give any results on account of disease prevalent among the caterpillars, in view of the fact that this species of *Limnerium* has been reared by Dr. L. O. Howard from the tussock moth at Washington, D. C. In Massachusetts, however, it has never been surely reared from this host, although large numbers of the tussock moth have been collected in various parts of the State and carefully studied at the Gipsy Moth Parasite Laboratory. It seems likely, therefore, that the *Limnerium* varies in habits in different parts of the country, or this apparent difference in host relationship may be ascribable merely to changes in its seasonal history brought about by a colder climate.

FIG. 33.—*Limnerium validum:* Egg. Enlarged about 120 times. (Original.)

FIG. 34.—*Limnerium validum:* Eclosion of larva. Enlarged about 120 times. (Original.)

NOTES ON DEVELOPMENT AND ANATOMY OF THE LARVA.

THE EGG.

The egg (figs. 33, 34) of *Limnerium validum* is elongate kidney-shaped or subcylindrical and rather convex on the dorsal side, slightly concave ventrally, with both poles bluntly rounded. The chorion is heavily chitinized, comparatively thick and resistant, and with a perfectly smooth surface. Its color is pale brown, or sometimes nearly white in the case of freshly deposited eggs, but not always, as fully colored eggs may be found in the oviducts of dissected females. In size the egg is about 0.35 to 0.41 mm. long and 0.13 to 0.14 mm. in transverse diameter.

Adult females freshly issued from cocoons were dissected on several occasions, and fully developed eggs to the number of 15 to 20 were found in the oviducts ready for oviposition. The female of this species therefore may perpetuate its kind almost immediately after its eclosion from the cocoon (fig. 32). It may also be parthenogenetic at times, as eggs that were laid by unfertilized females in the preceding experiments hatched freely. Not enough evidence was gained to state positively whether unfertilized eggs always produce males, but this is probably true.

THE FIRST-STAGE LARVA.

DESCRIPTION OF THE NEWLY HATCHED LARVA.

The first stage of the larva of *Limnerium* is characterized by 13 segments, including the comparatively heavily chitinized head, and a long tapering ventral appendage of the last body segment. In the case of newly hatched larvæ (fig. 35) the head is about one-half as long as the body, excluding the tail appendage, and is bent to the axis of the body at an angle of about 45°. Its dorsal margin is strongly curved, especially anteriorly; the ventral margin is much shorter and only slightly curved. The integument of the head is rather heavily chitinized and is slightly pigmented with brown. It has a slight ridge on each side running backward from the insertion of the mandibles, and separating the gula from the cheeks. The gula seems to be but slightly hollowed out and is as heavily armored as the rest of the head.

FIG. 35.—*Limnerium validum:* First-stage larva, newly hatched. Enlarged about 120 times. (Original.)

The mouthparts (fig. 37) consist of prominent, curved and sharply pointed mandibles, crossing each other at the tips, and projecting somewhat downward into the large mouth cavity. The aperture of the mouth is surrounded by a raised, chitinized, circular rim, about 0.037 mm. in diameter, and with a broad inner margin. The posterior inner margin is a heavily chitinized plate, with two prominent teeth separated by an angular median indentation.

The body in the thoracic region is nearly as broad as the head but rapidly tapers posteriorly. The thin, delicate, transparent integument is thrown into folds on the dorsum and venter, but appar-

ently not on the sides. Each fold on the venter represents a body segment, though some may be more or less double; the folds on the dorsum, however, are plainly double, as two occur on each segment. The body is thus found to be 12-segmented, excluding the tail appendage which is plainly a ventral outgrowth of the last segment.

The appendage itself sometimes appears to be distinctly ringed, due undoubtedly to the folding of the integument. It is slender, tapering, and about four-fifths as long as the body. During embryonic development it is bent sharply forward and appressed to the venter; after eclosion it is bent to the axis of the body for a short period at an angle of about 90°, though later in life it extends straight backward. Its color and that of the body is transparent whitish.

The total length of the newly hatched larva is about 0.64 mm.; without tail, only 0.41 mm.; the width of the head is 0.11 mm. and that of the thorax 0.10 mm.

FUNCTION OF THE TAIL APPENDAGE.

In case of larvæ observed immediately after hatching, the tracheal system could be made out easily, and was filled with air without doubt, though necessarily of the closed or apneustic type. Only one fine tracheal branch could be distinguished in the tail, and it was clearly not important enough to indicate that the tail is a tracheal gill. The function of the tail, however, is probably respiratory, and the organ might properly be termed a blood gill. There is nothing in its structure to contradict this view, as it is a simple, hollow tube lined with hypodermal cells, and undoubtedly filled with blood a greater part of the time. Since the larva lies free in the body cavity of the host it is constantly bathed in blood and lymph fluids, from which the oxygen of its own blood must be derived through the delicate integument of the tail, or other parts of the body, especially while still small.

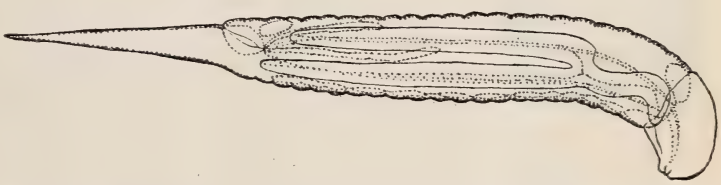

FIG. 36.—*Limnerium validum:* First-stage larva of large size, showing silk glands and nervous system. Enlarged 50 times. (Original.)

APPEARANCE OF OLDER LARVÆ.

The larva makes its escape from the egg by bursting open the chorion irregularly at the anterior pole (fig. 34), possibly with the aid of the mandibles. After hatching it develops rapidly if located in a suitable host, and molts for the first time in probably about 7 to 10

days. Before molting it attains a length of nearly if not quite 2 mm., for some larvæ were found, evidently nearly full-sized, about 1.7 mm. long. It now differs considerably in appearance from newly hatched larvæ, as a comparison of figures 35 and 36 will indicate. The head, being heavily chitinized, has remained the same size, but the body has grown until it is about five times as long as the head instead of only twice as long, as at first. The tail has also increased in size, but not proportionately to the growth of the body. Because of this rapid growth the folds of the integument so noticeable in newly hatched larvæ have largely disappeared, but are still discernible as slight creases, and afford the only means whereby the segments of the body may be distinguished.

NOTES ON THE ANATOMY OF THE LARVA.

The development of the viscera as made out in stained and mounted specimens is not without interest. Toward the end of the first instar the sericteries become the most conspicuous organs in the body, thus forecasting the prime importance of the cocoon-spinning habit as a protection during the pupal period. There is a pair of these silk glands which seem to start blindly in the first body segment and extend backward after branching once to the eleventh or twelfth segment. In reality, however, they are connected anteriorly with a minute tube which runs forward to the mouth. The glands themselves are also tubular and composed of comparatively enormous cells, with large oval nuclei.

FIG. 37.—*Limnerium validum:* Mouth-parts of first-stage larva. Enlarged about 250 times. (Original.)

The proctodæum is also conspicuous and extends forward only to the anterior end of the twelfth body segment. It is a thick-walled, ovoid organ, and although contiguous with the posterior end of the mesenteron, it does not communicate therewith. At the anterior end it gives rise to four large Malpighian tubules which extend forward into the ninth or even the eighth segment. The anus appears as a distinct opening at the end of the twelfth segment on the dorsal side, thus proving that the tail is a ventral outgrowth of the last segment. As the anus is distinctly open, there is no reason why the secretions of the Malpighian tubules may not be passed off into the blood of the host.

The brain toward the end of the first instar is crowded partly out of the head and becomes a conspicuous organ of the first body segment. The same phenomenon takes place in regard to the infræsophageal ganglion. Twelve ventral ganglia may be distinguished, of which the first 5 are closely united to each other and to the infræsophageal ganglion, the following 5 being separated by commissures, but the last 2 are also conjoined.

THE SECOND-STAGE LARVA.

The larva after the first molt differs conspicuously from the first-stage larva in respect to the soft, unarmored head, and the much shorter tail appendage (fig. 38). The mouth and its parts are also considerably changed.

The head is still large and prominent and has much the same general shape as in the first stage, although considerably shorter. Its

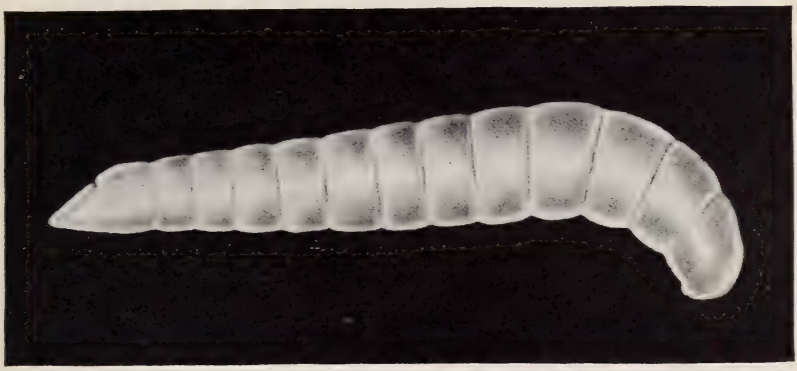

FIG. 38.—*Limnerium validum:* Second-stage larva. Enlarged about 30 times. (Original.)

integument is soft and pliable like that of the body. The mouth-parts (fig. 39) consist of a slightly bilobed, simple labium, and two strong, curved mandibles, which project downward into the large funnel-shaped mouth cavity. The body is distinctly cylindrical and tapers but little behind. Twelve segments in the body may be easily distinguished, the last one of which is prolonged ventrally into a short, conical tail appendage.

Only a few larvæ in this stage were found, and they were all about 2.2 mm. long. The duration of this stage is probably short, perhaps not more than from 5 to 7 days.

FIG. 39. — *Limnerium validum:* Mouthparts of second-stage larva. Enlarged about 100 times. (Original.)

THE THIRD-STAGE LARVA.

DESCRIPTION OF THE FULL-GROWN LARVA.

When the larva has obtained its full size and leaves the host it is from 9 to 10 mm. long, and pinkish white in color. It is like the usual hymenopterous type of larva (fig. 40), and the body is rather deeply twelve-segmented. The head is comparatively small and inconspicuous, and the tail appendage, so characteristic of the first stage and still persistent in the second stage, is now entirely lacking.

The mouth parts (fig. 41) are decidedly different from those in the preceding stages. They consist of strong mandibles, supported by two short, longitudinal, heavily chitinized ridges, and two long, transverse ridges that extend nearly to the lateral margins of the

head. Below the mandibles is a more or less circular labium with heavily chitinized margins, supported by two short transverse ridges. The mouth opening is small and hardly distinguishable, but probably lies directly beneath the tips of the mandibles, toward which

FIG. 40.—*Limnerium validum:* Third-stage larva. Enlarged about 8 times. (Original.)

point there is a gentle declivity. Just in front of the deeply concave, anterior end of the labium, in fact at the bottom of this concavity, is located the external opening of the sericteries. Above the mandibles are two large, circular, slightly pigmented spots, which undoubtedly mark the place where the compound eyes of the adult are beginning to develop.

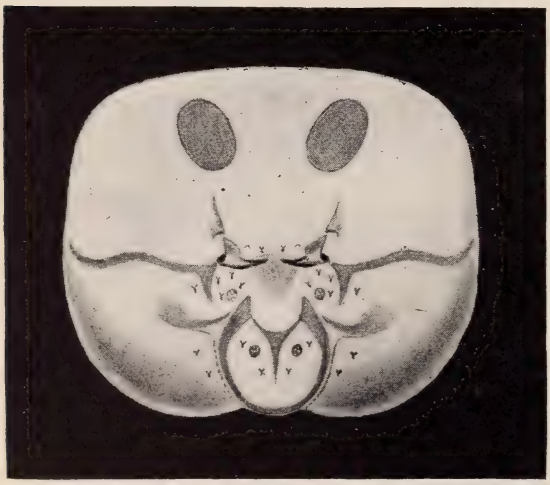

FIG. 41.—*Limnerium validum:* Anterior view of head of third-stage larva, showing mouthparts. Enlarged about 60 times. (Original.)

FEEDING HABITS OF THE IMPRISONED LARVA.

With a clear understanding of the mouth structures in the three stages, we may briefly consider the feeding habits of the imprisoned larva. The old accepted theory up to the time of Ratzeburg was that internal parasitic larvæ feed upon the fat-body of the host. Ratzeburg (1844), however, was forced to replace this theory with one that is probably more nearly correct. He concluded that such larvæ feed upon the lymph and blood of the host rather than upon any of the solid tissues. This view seems especially applicable to the feeding habits of *Apanteles* and related genera, which often leave the host in a living though comatose condition, but as the mandibles are

well developed in all three larval stages in the case of *Limnerium*, we hesitate to apply it in entirety to this species. We do not believe, however, that the larvæ of *Limnerium* while small actively attack and devour any of the solid tissues of the host including the fat-bodies, but rather institute pathological changes whereby these tissues become available for food. The first tissues to be broken down are the fat-bodies, whereas the vital organs, including the digestive tube, resist dissolution until the last. The very apparent, early disappearance of the fat-body in parasitized caterpillars probably accounts for the old theory that the parasite consumes it directly. The parasite certainly does consume the fat-body, but only after it has been broken down. We have often noticed this condition of the fat-body in apparently healthy caterpillars that harbored the early stage of almost any hymenopterous parasite. In such cases the fat-bodies were broken down more or less completely into their component parts, and the blood of the host was filled with the perfectly globular fat cells of varying sizes, and sometimes of a truly enormous size for individual cells. These small, solid particles, we believe, are as readily eaten by the larvæ of *Limnerium*, at least, as the fluid medium in which they float about within the body of the host. The mouth-parts in the first and second stages of *Limnerium* are admirably adapted for this purpose, being in fact a sucking apparatus, with strong, pointed mandibles, so placed as to aid in swallowing small, solid particles. In the third stage the mouthparts are still essentially sucking, but as the mouth opening is surrounded by chitinized, supporting or possibly rasping ridges, there is some ground for believing that even solid tissues may now be taken in, even before they have been wholly disintegrated. When the parasite reaches this stage, the host has become somewhat weakened, its fat-body having been almost entirely, and its body fluids greatly, depleted. Unlike the condition produced by some larvæ of tachinids at this stage in their development, the remaining tissues never dissolve into a putrid or semiputrid mass, but at all events remain clear and wholesome. To just what extent the tissues are broken down before being consumed has not been definitely determined, but we believe usually to a semiliquid condition in the case of *Limnerium*. A caterpillar forsaken by a larva of the *Limnerium* was closely examined, and a small amount of tissue was found at the posterior end of its body. This tissue was probably the remains of the muscles of that region, and appeared to be of a mucilaginous consistency.

RESPIRATION OF THE LARVA IN THE THIRD STAGE.

The shortening of the tail appendage in the second stage and its entire disappearance in the third stage must necessitate a gradual change in the respiratory habit of the larva, if, indeed, the tail is a

truly respiratory organ, as we think it must be. This change is perhaps correlated with the more ravenous appetite of the parasite in the last two stages of its larval life, and also with the gradual disappearance of the blood and lymph of the host. With the disappearance of the fluids of the host, the tail as a blood gill must necessarily become useless, as it is fitted for life in a fluid medium only. Nor does it seem possible, for much the same reason, that the larva's whole supply of oxygen is gained by osmosis through the integument of the body itself, for as the larva grows older the integument becomes thicker and tougher, especially in the last stage. The only alternative left is to consider that the oxygen is derived from the comparatively enormous amount of food taken in during this period, and that it is absorbed by the blood of the larva through the walls of its digestive tube. In other words, if the larva stopped feeding it would not only starve but also suffocate. Toward the end of the third stage, however, when the host is nearly or possibly not entirely consumed the stigmata become open, and the larva is able to breathe air directly, as it certainly does after leaving the host to spin its cocoon.

THE COCOON.

The cocoon has been aptly described by Dr. L. O. Howard (1897) in his bulletin on the parasites of the white-marked tussock moth, and we take the liberty of transcribing his words here: "The cocoon is rather long ellipsoidal, averaging 7.5 mm. in length by 2.8 mm. in greatest diameter. It is composed of two distinct coverings, the outer one of weak, close-spun, crinkly, gray, or grayish-brown silk, readily peeling off in a sheet, and the inner one close, tough, parchmentlike, dark brown in color, with golden reflections, of the type common among the Ophioninæ."

RESULTS OF THE DISSECTIONS OF HYPHANTRIA DURING THE FALL OF 1910.

During the late summer and the fall of 1910 a large series of collections of the fall webworm (*Hyphantria cunea* Drury) was brought together at the Gipsy Moth Parasite Laboratory, and an extensive study made of its parasites by means of dissection and rearing work. Most of the work was conducted by Mr. J. D. Tothill, who kindly turned over to the writer, together with his notes, the series of larvæ of *Limnerium* that were found during the course of the dissections. Inasmuch as another species of *Limnerium* is found attacking the fall webworm in Massachusetts rather abundantly, the collection of larvæ may have included *L. pilosulum* as well as *validum*, but the most careful scrutiny of the larvæ, all of which were mounted in balsam and in the first stage, failed to reveal any characters to sepa-

rate the series into the two species, so that some doubt remains whether *L. pilosulum* was actually represented.

The two most important lots of the larvæ were obtained respectively on August 18, from third-stage hosts collected the day previously at Reading Highlands, Mass., and on September 6 to 9, from mostly sixth-stage hosts collected near the laboratory at Melrose Highlands. The former lot may have been *L. pilosulum*, as this species spins its cocoon inside of the skin of small hosts and issues therefrom throughout the month of September. The latter lot of larvæ seems to have been *L. validum* without any doubt, as they were in the first stage when *L. pilosulum* was already beginning to issue as imagos, and inasmuch as they were found in rather large sixth-stage hosts. It seems reasonable to conclude, therefore, that the first-stage larvæ of these two species are practically identical in structure and appearance.

The disposition of the larvæ in their natural host is not without interest. According to Mr. Tothill's notes, they were found free in the body cavity, between the walls of the body and the alimentary canal, either inferior or superior to the latter. No indication of amœbocytosis was encountered during the course of the dissections.

GENERAL SUMMARY.

Limnerium validum (Cresson), a common parasite of the fall webworm (*Hyphantria cunea* Drury), readily attacks the caterpillars of the brown-tail moth, gipsy moth, and rusty vaporer moths, and also the tent caterpillar, when placed in confinement with these hosts, but is able to complete its transformations in the last species only and even then in but a small percentage of cases. Its larvæ seem to be totally unadapted for life in the caterpillars of the three former species, and fail to survive the protective reactions of the host, which are visibly manifested by an accumulation of active blood cells or amœbocytes around the larvæ, the cast eggshells, and even the eggs themselves. The amœbocytes presumably attack the living eggs and larvæ, or at least ultimately efface the latter entirely. The same reaction takes place in the case of the tent caterpillar, but a few of the larvæ are able to complete their transformations. Adaptation here is partially in evidence, and may be due to larval secretions which ward off the protective reactions of the host.

The egg of *Limnerium* has a thick, chitinized chorion, which resists decomposition in the body fluids of the host to a remarkable degree. The first-stage larva is characterized by a long, tapering tail appendage, evidently adapted for a respiratory function and acting as a blood gill. The second-stage larva has a much shorter appendage, and the third-stage larva has none, so that respiration very likely occurs through the walls of the digestive tube, oxygen

being absorbed from the constantly ingested supply of fresh tissues of the host.

The larva while still small assumes a more or less definite position in the body cavity of the host, and generally lies toward the posterior half of the body, either above or below the digestive tract and with its head directed caudad in respect to the host. During its whole life the larva feeds on blood and lymph and on small solid particles which result from the disintegration of the host's tissues, probably pathologically induced by some larval secretion. There is no evidence to show that such definite organs of the host as the digestive tube and muscular tissue can be consumed by the larva unless they are broken down, inasmuch as the mouthparts of the larva throughout life are essentially sucking.

Under artificial conditions the minimum time needed for the development of the insect from the egg to the adult was found to be about 50 days, but the maximum time may be extended many months. Under natural conditions in the Northern States as a parasite of *Hyphantria*, the females are probably active in parasitizing the caterpillars throughout the month of August and the first part of September. The larvæ issue from the caterpillars and spin their cocoons during September and the first part of October, but the cocoons always overwinter, and the adults emerge the following summer.

BIBLIOGRAPHY.

1864. Cresson, E. T.—Proc. Ent. Soc. Phila., vol. 3, p. 258.

1879. Provancher, L.—Nat. Canad., vol. 11, p. 174, fig. 9, a.

1883. Provancher, L.—Fauna Ent. Can. Hym., p. 367, fig. 44, a.

1890. Ashmead, W. H.—Proc. U. S. Nat. Mus., vol. 12, p. 429.

1844. Ratzeburg, F. T. C.—Die Forstinsecten.

1896. Cuenot, L.—Études physiologiques sur les Orthoptères. (Phagocytose.) Arch. Biol., vol. 14, pp. 315–325.

1897. Howard, L. O.—A study in insect parasitism. Tech. Ser. 5, Bur. Ent., U. S. Dept. Agr., p. 23, fig. 10.

1906. Janet, C.—Remplacement des muscles vibrateurs du vol par des colonnes d'Adipocytes, chez les fourmis après le vol nuptial. C. R. Acad. Sci., vol. 142, pp. 1095–1098.

1907. Janet, C.—Histolyse sans phagocytose, des muscles vibrateurs du vol, chez des reines des fourmis. C. R. Acad. Sci., vol. 144, pp. 393–396.

1910. Pantel, J.—Recherches sur les Diptères a larves entomobies. (Manifestations éventuelles de la réaction défensive.) La Cellule, vol. 26, pp. 158–160.

ADDITIONAL COPIES of this publication may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents per copy.

INDEX.

Page.

Ablerus clisiocampæ, not parasite of *Clisiocampa* but of *Chionaspis furfura* 10
Achillea millefolium, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves... 48
Acrobasis caryæ, secondary host of *Perilampus* sp..... 62
Ambrosia, adults of *Perilampus* on leaves..... 48
Amœbocytosis—
  as a protective reaction against *Limnerium validum* in caterpillars of *Euproctis chrysorrhœa*..... 75–76
  why does it not occur in hosts infested by their normal parasites?..... 76–77
Anastatus—
  larvæ in eggs of *Porthetria dispar* not attacked by *Perissopterus javensis*.... 12
  parasites of lepidopterous eggs 1
  possible host of *Tyndarichus navæ*..... 7
Anastatus bifasciatus—
  important introduced parasite of gipsy-moth eggs..... 1–2, 7–8
  probable host of *Pachyneuron gifuensis*..... 8
  parasite, synonyms..... 7–8
Angelica atropurpurea, adults of *Perilampus cyaneus* taken on leaves..... 48
Anobium molle, host of *Perilampus angustatus*..... 64
Anomalon ambiguum—
  parasite of *Hyphantria textor*..... 45
  probable host of *Perilampus hyalinus*..... 45
Anthonomus grandis, recorded as host of *Perilampus*, record open to question.. 63
Anthrenus verbasci, enemy of *Hemerocampa leucostigma*..... 2
Apanteles—
  fulvipes var. *japonica*, host of *Perilampus inimicus* 66
  host of *Perilampus hyalinus*..... 53
  hyphantriæ, host of *Perilampus hyalinus*..... 44, 62
  hyphantriæ, parasite of *Hyphantria textor*..... 36, 62
  oviposition far from head of caterpillar host, reasons therefor..... 73
  parasite of *Hyphantria cunea*..... 72
  parasite of *Hyphantria textor*..... 34
  sp., host of *Perilampus* sp..... 66
  sp., parasite of brown-tail moth..... 66
  sp., parasite of *Euchætias egle*, host of *Perilampus hyalinus*..... 62
  vimenetorum, host of *Mesochorus*..... 67
  vimenetorum, parasite of brown-tail moth..... 67
Apatela haustulifera, secondary host of *Perilampus* sp..... 62
Aphelininæ..... 11–12
Aphelinini..... 11–12
Aphis, *Pachyneuron gifuensis* reared therefrom, probably as hyperparasite..... 8
Athalia colibri, host of *Perilampus italicus*..... 65
Atoposoma—
  Atoposomoidea compared therewith in description..... 9
  A. variegatum the type..... 11
  comparison with *Zagrammosoma*..... 9
  variegatum, type of *Atoposoma*, parasite of *Œcophyllembius neglectus*..... 11

Page.
Atoposomoidea, new genus, description 9–11
Atoposomoidea ogimæ, new species, description, host, probably not a parasite of *Porthetria dispar* 9–11
Bees, parasitic, rôle as carriers of triungulins 38
Blepharipa scutellata—
host of *Perilampus cuprinus* 65, 66, 69
parasite of gipsy moth 65
Brown-tail moth—
(See also *Euproctis chrysorrhœa*.)
host of *Apanteles* sp 66
host of *Apanteles vimenetorum* 67
host of *Compsilura concinnata* 28
host of *Meteorus* and *Zygobothria nidicola* 77
tachinid parasites 65
Campoplex—
cocoons erroneously thought to be those of *Perilampus violaceus* 64–65
parasite of tortricid 64–65
Carpocapsa pomonella, host of *Perilampus levifrons* 64
Chalcididæ 13–20
Chalcidinæ 13–20
Chalcidini 13–20
Chalcidoid parasites, descriptions of certain species, paper 13–24
Chalcis—
belfragei in table of species of genus 14
callipus in table of species of genus 15
callipus, reference to original description, systematic notes, host 20
coloradensis in table of species of genus 14–15
coloradensis, reference to original description, systematic notes 16
columbiana in table of species of genus 15
fiskei in table of species of genus 14
fiskei, new species, description, hosts 16–17
flavipes in table of species of genus 14
flavipes, reference to original description, systematic notes, parasite of *Porthetria dispar* 18
fonscolombei in table of species of genus 15
fonscolombei, reference to original description, hosts, systematic notes 20
incerta in table of species of genus 14
incerta, reference to original description, systematic notes, habitat 16
minuta, C. paraplesia compared therewith 19
minuta in table of species of genus 14
minuta, reference to original description, systematic notes, hosts 18
obscurata in table of species of genus 14
obscurata, reference to original description, systematic notes, parasite of *Porthetria dispar* 17
ovata, C. minuta compared therewith 18
ovata, C. obscurata compared therewith 17
ovata in table of species of genus 14
ovata, reference to original description, systematic notes 15
paraplesia in table of species of genus 14
paraplesia, new species, description, hosts 19
pedalis in table of species of genus 14
robusta in table of species of genus 14
robusta, reference to original description 15

Chalcis—Continued. Page.
slossonæ in table of species of genus ... 15
table of species ... 14–15
tachinæ indistinguishable from *C. coloradensis* ... 16
tarsata in table of species of genus ... 14
tegularis in table of species of genus ... 14
Chionaspis furfura, host of *Ablerus clisiocampæ* ... 10
Chrysopa, host of *Isodromus iceryæ* ... 10–11
Chrysopa spp., hosts of *Perilampus* spp ... 62–63
Clisiocampa, not host of *Ablerus clisiocampæ* ... 10
Coccyx buoliana, host of *Perilampus levifrons* ... 64
Codling moth. (See *Carpocapsa pomonella*.)
Compsilura concinnata—
host of *Perilampus cuprinus* ... 65–66
host of *Perilampus hyalinus* ... 62
parasite of gipsy moth ... 65
parasite of gipsy moth and brown-tail moth ... 28–29
parasite of *Hyphantria textor* ... 62
Crawford, J. C., paper, "Descriptions of Certain Chalcidoid Parasites" ... 13–24
Cynips bifasciata=*Anastatus bifasciatus* ... 7
Dasypyga alternosquamella, secondary host of *Perilampus* sp ... 62
Dermestid enemy of *Porthetria dispar* ... 2
Derostenus, Japanese species of Ashmead belong in *Pleurotropis* ... 22
Dibrachys boucheanus—
host of *Perilampus hyalinus* ... 62
parasite of *Limnerium validum* ... 55
parasite of *Varichæta* ... 55, 62
Dibrachys reared from gipsy-moth pupæ ... 28
Dimmockia—
incongrua, parasite of *Varichæta aldrichi* ... 35
secundus, new species, description, host ... 24
Dryophilus pusillus, host of *Perilampus angustatus* ... 64
Elachertinæ ... 9–11
Elachertine parasite of *Lithocolletis fitchella* ... 11
Elachertine parasites of lepidopterous leaf-miners ... 11
Elachertini ... 9–11
Encyrtidæ ... 2–8
Encyrtinæ ... 2–7
Entedoninæ ... 22–23
Entedonini ... 22–23
Erigeron canadensis, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves ... 48
Euchætias egle, secondary host of *Perilampus hyalinus*, parasite ... 61–62
Eucharidæ and Perilampidæ, relationship ... 59–60
Eucosma desertana, secondary host of *Perilampus* sp ... 62
Eucosma scudderiana, secondary host of *Perilampus* sp ... 62
Eulophidæ ... 9–12, 22–24
Eulophinæ ... 24
Eulophini ... 24
Eupatorium perfoliatum, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves ... 48
Eupelminæ ... 7–8
Eupelmini ... 7–8
Eupelmus bifasciatus=*Anastatus bifasciatus* ... 7

Euproctis chrysorrhœa—
(See also Brown-tail moth.) Page.
as possible host of *Limnerium validum*, experiments 73–78
oviposition of *Limnerium validum* on small caterpillars 71
Euvanessa antiopa as possible host of *Limnerium validum*, experiments 83
Exocentris punctipennis, host of *Perilampus levifrons* 64
Exochilum, host of *Perilampus hyalinus* 45
Exorista blanda reared from gipsy-moth pupæ 28
Frontina frenchii, parasite of *Samia cecropia*, host of *Perilampus hyalinus* 62
Gaurax anchora (?), found in gipsy-moth pupæ 28
Gipsy moth—
(See also *Porthetria dispar* and *Ocneria dispar*.)
host of *Apanteles fulvipes* var. *japonica* 66
host of *Compsilura concinnata* 28–29
parasites reared or supposed to have been reared from eggs, paper 1–12
tachinid parasites 65
Glyptapanteles japonicus—
host of *Atoposomoidea ogimæ* 10
host of *Dimmockia secundus* 24
host of *Hypopteromalus apantelophagus* 21
host of *Perilampus inimicus* 20
host of *Pleurotropis howardi* 23
host of *Pleurotropis orientalis* 23
sp., host of *Hypopteromalus pœcilopus* 22
Grasshoppers, hosts of Sarcophagidæ 25
Halias quercana, host of *Perilampus ruficornis* 64
Harrisina americana—
recorded as host of *Perilampus platygaster* 62
secondary host of *Perilampus* sp 62
Helianthus, adults of *Perilampus* on leaves 48
Hemerocampa leucostigma—
as host of *Limnerium validum*, experiments 83
eggs eaten by *Anthrenus verbasci* 2
host of *Limnerium validum* 72
Hippocephalus multilineatus—
= *Zagrammosoma multilineatum* 11
parasite of *Lithocolletis ornatella* 11
Hister picipes, host of *Perilampus micans* 64
Hornet, host of *Rhipiphorus* 60
Howard, L. O., paper, "The Parasites Reared or Supposed to have been Reared from the Eggs of the Gipsy Moth" 1-12
Hylophila bicolorana, host of *Perilampus ruficornis* 64
Hypermetamorphism in *Perilampus*, *Orasema*, and *Rhipiphorus* 6
Hyphantria cunea—
host of *Apanteles* 72
host of *Limnerium pilosulum* 72
host of *Limnerium validum* 72
host of *Meteorus* 72
no amœbocytosis in caterpillars parasitized by *Limnerium validum* 75-76
results of dissections of larvæ with regard to parasitism by *Limnerium validum* and perhaps *L. pilosulum* 90-91
Hyphantria, primary host of *Limnerium fugitivum* and secondary host of *Perilampus hyalinus* 63

Page.
Hyphantria textor—
host of *Anomalon ambiguum* ... 45
host of *Ichneumon cinctitarsis* ... 45
host of *Melanichneumon* sp ... 45
parasites ... 34
secondary host of *Perilampus hyalinus*, parasites ... 61-62
Hypopteromalus—
apantelophagus in table of species of genus ... 21
apantelophagus, new species, description, host ... 21
pœcilopus in table of species of genus ... 21
pœcilopus, new species, description, host ... 21-22
tabacum in table of species of genus ... 21
table of species ... 21
Icerya purchasi not host of *Isodromus iceryæ* ... 10-11
Ichneumon—
cinctitarsis, parasite of *Hyphantria textor* ... 45
cinctitarsis, probable host of *Perilampus hyalinus* ... 45
host of *Perilampus hyalinus* ... 45
Isodromus iceryæ, not parasite of *Icerya purchasi* but of *Chrysopa* ... 10–11, 63
Larch sawfly. (See *Nematus erichsonii*.)
Leaf-miners, lepidopterous, elachertine parasites ... 11
Lepidopterous eggs, hymenopterous parasites in America ... 1
Limnerium—
fugitivum, parasite of *Hyphantria* and host of *Perilampus hyalinus* ... 63
parasite of *Hyphantria textor* ... 34
pilosulum, habits, possible occurrence in larvæ of *Hyphantria cunea* dissected ... 90–91
pilosulum, parasite of *Hyphantria cunea*, habits compared with those of *L. validum* ... 72
two species, hosts of *Perilampus hyalinus* ... 44
Limnerium validum—
anatomy of first-stage larva, notes ... 86
as possible parasite of *Euproctis chrysorrhœa*, experiments ... 73–78
as possible parasite of *Malacosoma americana*, experiments ... 78–81
as possible parasite of *Notolophus antiquus* ... 81–82
as possible parasite of *Porthetria dispar* ... 82–83
behavior in confinement ... 73
bibliography ... 92
biology, paper ... 71–92
cocoon ... 90
development and anatomy of larva, notes ... 83–90
egg ... 83–84
experiments with possible hosts ... 72–83
feeding habits of imprisoned third-stage larva ... 88–89
host of *Dibrachys boucheanus* ... 55
host of *Perilampus hyalinus* ... 43–44, 49–55, 62
hosts ... 72–83, 90–92
is it a host of *Perilampus* "species A"? ... 55–57
larvæ, older, of first-stage, appearance ... 85–86
larva, first-stage ... 84–86
larva, full-grown, description ... 87–88
larva, newly hatched, description ... 84–85
larva, second-stage ... 87

Limnerium validum—Continued. Page.
larva, third-stage ... 87–90
length of stages in life history ... 80
parasite of *Hyphantria cunea* ... 91–92
parasite of *Hyphantria textor* ... 36–62
parasite of *Melalopha inclusa* ... 62
rearing apparatus and methods ... 72–73
respiration of larva in third-stage ... 89–90
results of dissections of host larvæ, *Hyphantria cunea* ... 90–91
summary of biology and host relations ... 91–92
tail appendage of larva, function ... 85
Lithocolletis fitchella, host of elachertine ... 11
Lithocolletis ornatella, host of *Hippocephalus multilineatus* (*Zagrammosoma multilineatum*) ... 11
Lyctus canaliculatus, host of *Perilampus micans* ... 64
Malacosoma americana as a possible host of *Limnerium validum*, experiments ... 78–81
Malacosoma, amœbocytosis in caterpillars as a protective reaction against *Limnerium validum* ... 75
Melalopha inclusa, secondary host of *Perilampus hyalinus*, parasite ... 61–62
Melanichneumon sp.—
parasite of *Hyphantria textor* ... 45
probable host of *Perilampus hyalinus* ... 45
Melanoplus bivittatus, host of sarcophagid ... 63
Melittobia, parasite of *Varichæta*, probably too small for host of *Perilampus* ... 55
Meloe ... 60
Mesochorus, parasite of *Apanteles vimenetorum* ... 67
Meteorus—
communis, parasite of *Hyphantria textor*, host of *Perilampus hyalinus* ... 62
(*communis*?), host of *Perilampus hyalinus* ... 44
fatal influence of larva over that of *Zygobothria nidicola* when occurring together in brown-tail moth caterpillars ... 77
oviposition far from head of caterpillar host, reasons therefor ... 73
parasite of brown-tail moth ... 77
parasite of *Hyphantria cunea* ... 72
Microplitis nigripennis, parasite of *Heliothis obsoleta* and host of *Perilampus hyalinus* ... 63
Mirini ... 2–7
Monodontomerus reared from gipsy-moth pupæ ... 28
Mourning-cloak butterfly. (See *Euvanessa antiopa*.)
Myodites, oviposition ... 60
Nematus erichsonii, planidium (*Perilampus*?) found on hibernating larva ... 59
Notolophus, amœbocytosis in caterpillars as a protective reaction against *Limnerium validum* ... 75
Notolophus antiquus as a possible host of *Limnerium validum*, experiments ... 81–82
Ocneria dispar—
(See also *Porthetria dispar* and Gipsy Moth.)
host of *Anastatus bifasciatus* ... 7
Oecophyllembius neglectus, host of *Atoposoma variegatum* ... 11
Ooencyrtus, parasites of lepidopterous eggs ... 1
Orasema—
development ... 57–59
mention ... 47
parasite of *Pheidole instabilis* and other ants ... 57–58
relationship to *Perilampus* ... 59

	Page.
Orasema viridis—	
comparison of pupa of *Perilampus hyalinus* therewith	47–48
larva	35–36
oviposition, habits of planidium	57–58
planidium, description	59
Pachyneurini	8
Pachyneuron gifuensis, bibliography, hosts reared from eggs of *Porthetria dispar*	8
Pachyneuron, host of *Tyndarichus navae*	7
Pales pavida—	
host of *Perilampus cuprinus*	65–66
parasite of brown-tail moth	65
Parasite introduction—	
relations of *Perilampus* to problem, paper	33–69
adaptation to hosts	76–77
Parasites reared or supposed to have been reared from eggs of gipsy moth, paper	1–12
Parexorista cheloniae—	
host of *Perilampus cuprinus*	65, 66
parasite of brown-tail moth	65
Pastinaca sativa, adults of *Perilampus hyalinus* taken on leaves	48
Patterson, T. L., paper, "Investigations into the Habits of Certain Sarcophagidæ"	25–32
Pentatomidæ, hosts of *Telenomus cultratus*	12
Perilampidæ	20
Perilampidæ and Eucharidæ, relationship	59–60
Perilampus—	
and its relations to problem of parasite introduction, paper	33–69
economic aspects	67–69
(?) emergence from parasitized *Hyphantria textor*	34
host relations of genus	61–67
parasite of Tachinidæ	63
planidium found on hibernating larva of *Nematus erichsonii*	59
relationship to *Orasema*	59–60
résumé of host relations of genus	66–67
Perilampus angustatus, recorded hosts	64
Perilampus auratus, recorded hosts	64
Perilampus cuprinus—	
economic status	68–69
hosts, probable life history	65–66
parasite of *Blepharipa scutellata*	69
Perilampus cyaneus, food habits of adult	48
Perilampus hyalinus—	
biology	34–55
development as influenced by temperature	49–51
economic status	68
effect of parasitism on host	51–52
food habits of adult	48
habits in comparison with those of *P. cuprinus*	66
hosts	42–45, 61–63
later larval stages	45–47
life cycle, length	49–51
longevity of adults	49
oogenesis	49
oviposition	37–38
parasite of *Limnerium fugitivum*	63

Perilampus hyalinus—Continued. Page.
parasite of *Microplitis nigripennis* ... 63
parasite of sarcophagid ... 63
parasite of *Varichæta* ... 68
percentage of parasitism ... 52–53
planidium, description ... 39–41
planidium, habits ... 41–45
pupation ... 47–48
relation with *Dibrachys boucheanus* as parasites of *Limnerium validum* ... 55
reproductive capacity ... 39
secondary parasite of *Heliothis obsoleta* ... 63
superparasitism ... 53–55
Perilampus inimicus—
host ... 66
new species, description, host ... 20
Perilampus italicus, recorded host ... 65
Perilampus levifrons, recorded hosts ... 64
Perilampus micans, recorded hosts ... 64
Perilampus platygaster, recorded as parasite of *Harrisina americana* ... 62
Perilampus ruficornis, recorded hosts ... 64–65
Perilampus, "species A," planidium, description and habits, comparison with that of *Perilampus hyalinus* ... 55
Perilampus sp., parasite of *Apanteles* sp ... 66
Perilampus violaceus=P. ruficornis ... 64
Perissopterus ... 11–12
Perissopterus javensis, parasite of *Tachardia* but probably not of *Porthetria dispar*, bibliography ... 11–12
"Phagocytosis," so called. (*See* Amœbocytosis.)
Pheidole instabilis, host of *Orasema viridis* ... 57–58
Phlyctænia extricalis, secondary host of *Perilampus* sp ... 62
Planidium, use and derivation of term ... 36
Pleurotropis—
atamiensis, probably belonging to an undescribed genus ... 13–22
bifoveolatus in table of species of genus ... 22
howardi in table of species of genus ... 22
howardi, new species, description, host ... 23
mitsukurii in table of species of genus ... 22
nawaii in table of species of genus ... 22
orientalis in table of species of genus ... 22
orientalis, new species, description, host ... 23
table of species ... 22
Porthetria dispar—
(See also Gipsy Moth and *Ocneria dispar*.)
as a possible host of *Limnerium validum* ... 82–83
host of *Anastatus bifasciatus* ... 8
host of *Chalcis flavipes* ... 18
host of *Chalcis obscurata* ... 17
host of *Schedius kuvanæ* ... 4–5
Pachyneuron gifuensis reared from eggs ... 8
probably not host of *Atoposomoidea ogimæ* ... 10
probably not host of *Perissopterus javensis* ... 11–12
relations of Sarcophagidæ thereto ... 25
reported host of *Chalcis callipus* ... 20
reported host of *Telenomus*, new species ... 12
Tyndarichus navæ reared from eggs ... 7

Page.
Proctotrypidæ 12
Pteromalidæ 8, 21-22
Pteromalinæ 21-22
Pteromalini 21-22
Rearing apparatus and methods for *Limnerium validum* 72-73
Retinia sp. (?), secondary host of *Perilampus* sp 62
Rhipiphorus paradoxus, life history in comparison with that of *Perilampus* and *Orasema* 60-61
Samia cecropia, secondary host of *Perilampus hyalinus*, parasite 61-62
Sarcophagid—
host of *Perilampus hyalinus* 63
reared from *Melanoplus bivittatus* 63
Sarcophagidæ—
habits with relation to gipsy moth, paper 25-32
hosts of *Chalcis fonscolombei* 20
hosts of *Chalcis minuta* 18
hosts of *Chalcis paraplesia* 19
Sarcophagids, probable hosts of *Perilampus cuprinus* 65
Scelioninæ 12
Schedius—
host of *Tyndarichus navæ* 7
kuvanæ, host of *Pachyneuron gifuensis* 8
kuvanæ, new species, description, parasite of *Porthetria dispar* 3-5
new genus, description 2-3
Tyndarichus compared thereto in description 5
Sitaris 60
Sium cicatæfolium, adults of *Perilampus cyaneus* taken on leaves 48
Smith, Harry S., paper, "The Chalcidoid Genus Perilampus and its Relations to the Problem of Parasite Introduction" 33-69
Solenius rubicola, host of *Perilampus auratus* 64
Solenius vagus, host of *Perilampus auratus* 64
Solidago canadensis, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves 48
Solidago juncea, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves 48
Sphegigasterinæ 8
Strepsiptera, reproductive capacity 39
Stylops, reproductive capacity 39
Tachardia, host of *Perissopterus javensis* 11
Tachinidæ, hosts of *Chalcis fiskei* 17
Tachinid hosts of *Perilampus cuprinus* 65, 66
Tachinids, parasites of *Hyphantria textor* 34
Tanacetum vulgare, adults of *Perilampus hyalinus* and *P. cyaneus* on leaves 48
Telenomini 12
Telenomus—
cultratus, parasite of Pentatomidæ 12
new species allied to *T. cultratus*, reported rearing from eggs of *Porthetria dispar* 12
parasites of lepidopterous eggs 1
Temperature as influencing development of *Perilampus hyalinus* 49-51
Theronia reared from gipsy-moth pupæ 28
Timberlake, P. H., paper, "Experimental Parasitism: A study of the biology of *Limnerium validum* (Cresson)" 71-92
Tortricid host of *Campoplex* 64, 65

Trichogramma— Page.
apparently unable to pierce gipsy-moth eggshell for oviposition 1
parasites of lepidopterous eggs 1
Tricholyga grandis—
host of *Perilampus cuprinus* 65-66
parasite of gipsy moth 65
Triungulins of parasitic beetles, carriage by parasitic bees 38
Trogoderma tarsale, enemy of Lepidoptera 2
Tussock-moth, white-marked. (See *Hemerocampa leucostigma*.)
Tyndarichus navæ—
habits of *Pachyneuron gifuensis* in comparison therewith 8
host of *Pachyneuron gifuensis* 8
new species, description, hosts, reared from eggs of *Porthetria dispar* 6, 7
Tyndarichus, new genus, description 5, 6
Vaporer moth, rusty. (See *Notolophus antiquus*.)
Varichæta—
comparison of life history with that of other tachinids in relation to parasitism by *Perilampus* 66
host of *Dibrachys boucheanus* 55-62
host of *Melittobia* 55
host of *Perilampus hyalinus* 68
Varichæta aldrichi—
host of *Dimmockia incongrua* 35
host of *Perilampus hyalinus* 42, 43, 49-55, 62
parasite of *Hyphantria textor* 36-62
Webworm, fall. (See *Hyphantria cunea* and *H. textor*.)
Zagrammosoma, *Atoposoma* compared therewith, parasite of Lepidoptera 9
Zagrammosoma multilineatum, *Hippocephalus multilineatus* a synonym 11
Zygobothria nidicola—
fatal influence of *Meteorus* larva upon it when larvæ of both species occur together in brown-tail moth caterpillars 77
parasite of brown-tail moth 77

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

TECHNICAL SERIES NO. 20.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL PAPERS ON MISCELLANEOUS FOREST INSECTS.

I. CONTRIBUTIONS TOWARD A MONOGRAPH OF THE BARK-WEEVILS OF THE GENUS PISSODES.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

II. THE GENOTYPES OF THE SAWFLIES AND WOODWASPS, OR THE SUPERFAMILY TENTHREDINOIDEA.

By S. A. ROHWER, *Specialist in Forest Hymenoptera.*

III. A REVISION OF THE POWDER-POST BEETLES OF THE FAMILY LYCTIDÆ OF THE UNITED STATES AND EUROPE.

By E. J. KRAUS, *Expert Preparator, Forest Insect Investigations.*

APPENDIX. NOTES ON HABITS AND DISTRIBUTION WITH LIST OF DESCRIBED SPECIES.

By A. D. HOPKINS, *In Charge of Forest Insect Investigations.*

IV. STUDIES IN THE SAWFLY GENUS HOPLOCAMPA.

By S. A. ROHWER, *Specialist in Forest Hymenoptera.*

V. A PRELIMINARY SYNOPSIS OF CERAMBYCOID LARVÆ.

By J. L. WEBB, *Entomological Assistant.*

VI. CHALCIDIDS INJURIOUS TO FOREST-TREE SEEDS.

By S. A. ROHWER, *Specialist in Forest Hymenoptera.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1921.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*

C. L. Marlatt, *Entomologist and Assistant Chief of Bureau.*

E. B. O'Leary, *Assistant to Chief.*

A. J. Leister, *Chief Clerk.*

Rolla P. Currie, *Editor.*

Mabel Colcord, *Librarian.*

W. D. Hunter, *in charge of southern field-crop insect investigations.*
W. R. Walton, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous-fruit insect investigations.*
F. H. Chittenden, *in charge of truck-crop insect investigations.*
E. A. Back, *in charge of stored-product investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
E. F. Phillips, *in charge of investigations in bee culture.*
A. F. Burgess, *in charge of gipsy moth and brown-tail moth investigations.*

Forest Insect Investigations.

A. D. Hopkins, *Forest Entomologist in Charge.*

J. M. Miller, *assistant forest entomologist;* H. E. Burke, W. D. Edmonston, T. E. Snyder, J. C. Evenden, *specialists in forest entomology;* S. A. Rohwer, *specialist in forest Hymenoptera;* A. G. Böving, *expert;* Carl Heinrich, *specialist in forest Lepidoptera;* F. B. Herbert, William Middleton, Raymond A. St. George, J. H. Pollock, *scientific assistants;* J. E. Patterson, W. E. Glendinning, George Hofer, *entomological rangers;* P. D. Hartman, *assistant entomological Inspector.*

PREFACE TO BULLETIN.

It is the purpose of this bulletin to include such miscellaneous technical papers on insects, other than the scolytid beetles, as are either injurious or beneficial and of more or less importance in their relation to American forests. These papers are based largely, if not entirely, on original observations and investigations, supplemented by material in the United States National Museum, and serve as a necessary basis for the nontechnical papers on the same insects. As they are intended to be of service especially to the economic entomologists and to the student of forest entomology, they are, as a rule, presented in a somewhat less formal style than if intended for the systematist only.

A. D. H.

CONTENTS.

	Page.
CONTRIBUTIONS TOWARD A MONOGRAPH OF THE BARK-WEEVILS OF THE GENUS PISSODES ..... *A. D. Hopkins* ..	1
Introductory	1
Historical references	2
Copy of original description of the genus	3
Translation of original description	3
List of species of *Pissodes* described previous to 1909, with recorded distribution and host trees	6
Taxonomy	8
Characters used by different authors	8
Subordinal and family characters	8
Tribal and subfamily characters	8
Revisional notes	9
Generic characters	9
Subordinal and family characters	9
Abdominal segments	9
Revised classification	10
Subordinal to subfamily characters	11
Generic characters	11
Anatomical details of the adult	12
The head	12
The thorax	17
The prothorax	18
The mesothorax	18
The metathorax	20
The abdomen	20
The wings	21
Internal anatomy	22
Secondary sexual characters	22
The eggs	23
The larva	23
The pupa	25
Host trees	26
General habits	26
General life history	27
General distribution	27
The North American species of *Pissodes*	27
Natural classification of the species	27
Statistical taxonomy	28
Morphological and physiological characters and characteristics ..	30
Key to the species	30
Synopsis of adult characters, with descriptions of new species	32
Synopsis of primary sexual characters	37
Synopsis of secondary sexual characters	37
Synopsis of pupal characters	38

CONTRIBUTIONS TOWARD A MONOGRAPH OF THE BARK-WEEVILS OF THE GENUS PISSODES—Continued.

The North American species of *Pissodes*—Continued. Page.

Synopsis of larval characters 39
Table of distribution 40
Table showing relation of species to host trees 41
Table of host trees 42
Characters common to the species of the genus 43
Characters common to the species of the major and minor divisions 43
Division I 43
Subdivision A 44
Section a1 44
Subsection b1 44
1. *Pissodes similis* 44
2. *Pissodes utahensis* 45
3. *Pissodes barberi* 45
Subsection b2 46
4. *Pissodes sitchensis* 47
5. *Pissodes engelmanni* 47
6. *Pissodes strobi* 48
7. *Pissodes approximatus* 49
8. *Pissodes schwarzi* 50
9. *Pissodes canadensis* 51
10. *Pissodes nemorensis* 51
11. *Pissodes deodaræ* 52
12. *Pissodes californicus* 53
13. *Pissodes yosemite* 53
14. *Pissodes webbi* 54
Section a2 55
Subsections b3 and b4 55
15. *Pissodes radiatae* 55
16. *Pissodes fasciatus* 56
Subdivision B 56
Section a3 57
17. *Pissodes costatus* 57
Section a4 58
Subsection b5 59
18. *Pissodes fiskei* 59
19. *Pissodes nigræ* 59
20. *Pissodes puncticollis* 60
21. *Pissodes murrayanæ* 60
22. *Pissodes coloradensis* 60
23. *Pissodes alascensis* 61
24. *Pissodes rotundatus* 61
Subsection b6 62
25. *Pissodes burkei* 62
26. *Pissodes piperi* 62
27. *Pissodes dubius* 63
28. *Pissodes fraseri* 63
Division II 64
29. *Pissodes affinis* 64
30. *Pissodes curriei* 65
List of described species of *Pissodes* 65
Bibliography 66

Page.

THE GENOTYPES OF THE SAWFLIES AND WOODWASPS, OR THE SUPERFAMILY TENTHREDINOIDEA ..... *S. A. Rohwer* .. 69
Introduction 69
An alphabetical catalogue of the generic names used in the Tenthredinoidea, with their type species 69
The designation of the type species of genera 69
Rules of zoological nomenclature for the designation of type species .. 71
Catalogue 72
An index to the genotypes 92
Synonymy of certain genera 98
The work of William H. Ashmead on the Tenthredinoidea 102
An alphabetical list of the genera of Tenthredinoidea described by William H. Ashmead, with the determined synonymy 103
Bibliography of the more important writings of William H. Ashmead on Tenthredinoidea 104
Description of the genera and species 104

A REVISION OF THE POWDER-POST BEETLES OF THE FAMILY LYCTIDÆ OF THE UNITED STATES AND EUROPE ..... *E. J. Kraus and A. D. Hopkins* .. 111
Introduction 111
History 112
The principal characters of the family Lyctidæ 114
Synopsis of genera 115
Revisional notes 115
Synopsis of species of the genus *Lyctus* 116
Systematic notes 121
Genus *Lyctus* Fabricius 121
Lyctus impressus Comolli 121
Lyctus punctatus (Le Conte) 121
Lyctus californicus Casey 121
Lyctus parallelopipedus (Melsheimer) 121
Lyctus curtulus Casey 122
Lyctus politus n. sp 122
Lyctus brunneus (Stephens) 123
Lyctus pubescens Panzer 123
Lyctus opaculus Le Conte 123
Lyctus suturalis Faldermann 124
Lyctus cavicollis Le Conte 124
Lyctus planicollis Le Conte 124
Lyctus parvulus Casey 125
Lyctus linearis (Goeze) 125
Genus *Lyctoxylon* Reitter 126
Lyctoxylon japonum Reitter 126
Genus *Minthea* Pascoe 126
Minthea rugicollis (Walker) 127
Minthea stichothrix (Reitter) 127
Bibliography 128
Appendix. Notes on habits and distribution, with list of described species. 130
Habits 130
Distribution 132
The Lyctidæ represented in the collections examined by Kraus and Hopkins (classification according to Kraus) 136
List of described species, with synonymy according to the literature and recent studies by the authors 137

Page.
STUDIES IN THE SAWFLY GENUS HOPLOCAMPA.....*S. A. Rohwer*.. 139
Introduction..... 139
Hoplocampa (*Macgillivrayella*) *pallida* n. sp..... 141
Hoplocampa (*Hoplocampa*) *orbitalis* n. sp..... 141
Hoplocampa (*Hoplocampa*) *koebelei* n. sp..... 142
Hoplocampa (*Hoplocampa*) *alpestris* n. sp..... 142
Hoplocampa (*Hoplocampa*) *californica* n. sp..... 143
Hoplocampa (*Hoplocampa*) *marlatti* n. sp..... 143
Hoplocampa (*Hoplocampa*) *nevadensis* n. sp..... 143
Hoplocampa (*Hoplocampa*) *xantha* n. sp..... 144
Hoplocampa (*Hoplocampa*) *occidentalis* n. sp..... 144
Hoplocampa (*Hoplocampa*) *montanicola* n. sp..... 145
Hoplocampa (*Hoplocampa*) *halcyon* (Norton)..... 145
Hoplocampa (*Hoplocampa*) *bioculata* Rohwer..... 146
Hoplocampa (*Hoplocampa*) *pallipes* Macgillivray..... 146
Selandria canadensis Provancher..... 146
Selandria flavicornis Provancher..... 146
Hoplocampa (*?*) *atriceps* Kirby..... 147
Hoplocampa lenis (Cresson) and *Hoplocampa spissipes* (Cresson)..... 147
Hoplocampa gentilis (Cresson) and *Hoplocampa montana* (Cresson)..... 147
Tenthredo (*Allantus*) *obtusa* Klug..... 147
Synoptic table to the Nearctic species of the subgenus *Hoplocampa*..... 147
A PRELIMINARY SYNOPSIS OF CERAMBYCOID LARVÆ.....*J. L. Webb*.. 149
Introduction..... 149
Superfamily Cerambycoidea..... 151
Family Lamiidæ..... 152
Family Cerambycidæ..... 153
Family Lepturidæ..... 154
Family Prionidæ..... 155
Family Asemidæ..... 155
CHALCIDIDS INJURIOUS TO FOREST-TREE SEEDS.....*S. A. Rohwer*.. 157
Introduction..... 157
Syntomaspis druparum..... 158
Megastigmus sp..... 159
Megastigmus brevicaudis..... 159
Megastigmus strobilobius..... 159
Megastigmus pinus..... 160
Megastigmus spermotrophus..... 160
Summary..... 162
Bibliography..... 162
INDEX..... 165

ILLUSTRATIONS.

PLATES.

Page

PLATE I. Classification of the genus *Pissodes*, showing technical and common names and species numbers 1

II. Statistical taxonomy of *Pissodes* 30

III. Adults of Pissodes. Fig. 1.—*P. similis*. Fig. 6.—*P. strobi*. Fig. 8.—*P. schwarzi*. Fig. 15.—*P. radiatæ*. Fig. 16.—*P. fasciatus*. Fig. 18.—*P. fiskei* 68

IV. Adults of *Pissodes*. Fig. 20.—*P. puncticollis*. Fig. 24.—*P. rotundatus*. Fig. 25.—*P. burkei*. Fig. 26.—*P. piperi*. Fig. 27.—*P. dubius*.—Fig. 29.—*P. affinis* 68

V. Larva and pupa of *Pissodes*. Fig. *A*.—*P. piperi*, larva—dorsal, lateral, and ventral aspects. Fig. *B*.—*P. sitchensis*, pupa—dorsal, ventral, and lateral aspects 68

VI. Pygal tergites of the abdomen of *Pissodes*. Fig. 5, ♀.—Tergite 7 of *P. engelmanni*. Fig. 5, ♂.—Tergites 7 and 8 of *P. engelmanni*. Fig. 6.—Tergites 7 and 8 of *P. strobi*. Fig. 7, ♂.—Tergites 7 and 8 of *P. approximatus*. Fig. 28, ♂.—Tergites 7 and 8 of *P. fraseri*; Fig. 28, ♀.—Tergite 7 of *P. fraseri*. Fig. 29, ♂.—Tergites 7 and 8 of *P. affinis*. Fig. 30, ♂.—Tergites 7 and 8 of *P. curriei* 68

VII. Female reproductive organs of *Pissodes* 68

VIII. Male and female reproductive organs of *Pissodes* 68

IX. Male reproductive organs of *Pissodes* 68

X. Forks of male genitalia of *Pissodes* 68

XI. Stems of male genitalia of *Pissodes* 68

XII. *Pissodes fiskei:* Work in inner bark and outer wood 68

XIII. *Pissodes sitchensis:* Work in terminal and top 68

XIV. *Pissodes strobi:* Work in terminals and tops 68

XV. Work of *Pissodes approximatus* and *P. nemorensis* in bark and wood of small sapling 68

XVI. Work of *Pissodes yosemite* and *P. schwarzi* in bark and wood 68

XVII. *Pissodes fasciatus:* Work in bark and outer wood 68

XVIII. *Pissodes piperi:* Work in bark 68

XIX. Distribution maps of *Pissodes*. Fig. 1.—*P. similis*. Fig. 2.—*P. utahensis*. Fig. 3.—*P. barberi*. Fig. 4.—*P. sitchensis*. Fig. 5.—*P. engelmanni*. Fig. 6.—*P. strobi*. Fig. 7.—*P. approximatus*. Fig. 8.—*P. schwarzi* 68

XX. Distribution maps of *Pissodes*. Fig. 9.—*P. canadensis*. Fig. 10.—*P. nemorensis*. Fig. 11.—*P. deodaræ*. Fig. 12.—*P. californicus*. Fig. 13.—*P. yosemite*. Fig. 14.—*P. webbi*. Fig. 15.—*P. radiatæ*. Fig. 16.—*P. fasciatus* 68

XXI. Distribution maps of *Pissodes*. Fig. 17.—*P. costatus*. Fig. 18.—*P. fiskei*. Fig. 19.—*P. nigræ*. Fig. 20.—*P. puncticollis*. Fig. 21.—*P. murrayanæ*. Fig. 22.—*P. coloradensis*. Fig. 23.—*P. alascensis*. Fig. 24.—*P. rotundatus* 68

Page.

PLATE XXII. Distribution maps of *Pissodes*. Fig. 25.—*P. burkei*. Fig. 26.—*P. piperi*. Fig. 27.—*P. dubius*. Fig. 28.—*P. fraseri*. Fig. 29.—*P. affinis*. Fig. 30.—*P. curriei* 68

XXIII. Fig. 1.—*Hoplocampa* (*Macgillivrayella*) *oregonensis:* Front view of head. Fig. 2.—*Hoplocampa* (*Hoplocampa*) *flava:* Front view of head. Fig. 3.—*Hoplocampa* (*Hoplocampa*) *orbitalis:* Saw. Fig. 4.—*Hoplocampa* (*Hoplocampa*) *montanicola:* Saw. Fig. 5.—*Hoplocampa* (*Hoplocampa*) *alpestris:* Saw. Fig. 6.—*Hoplocampa* (*Hoplocampa*) *koebelei:* Saw. Fig. 7.—*Hoplocampa* (*Hoplocampa*) *pallipes:* Saw. Fig. 8.—*Hoplocampa* (*Hoplocampa*) *halcyon:* Saw. Fig. 9.—*Hoplocampa* (*Hoplocampa*) *nevadensis:* Saw 148

XXIV. Fig. 1.—*Hoplocampa* (*Hoplocampa*) *xantha:* Sheath. Fig. 2.—*Hoplocampa* (*Hoplocampa*) *pallipes:* Sheath. Fig. 3.—*Hoplocampa* (*Hoplocampa*) *koebelei:* Sheath. Fig. 4.—*Hoplocampa* (*Hoplocampa*) *nevadensis:* Sheath. Fig. 5.—*Hoplocampa* (*Hoplocampa*) *alpestris:* Sheath. Fig. 6.—*Hoplocampa* (*Hoplocampa*) *montanicola:* Sheath. Fig. 7.—*Hoplocampa* (*Hoplocampa*) *marlatti:* Sheath. Fig. 8.—*Hoplocampa* (*Hoplocampa*) *occidentalis:* Sheath. Fig. 9.—*Hoplocampa* (*Hoplocampa*) *halcyon:* Sheath. Fig. 10.—*Hoplocampa* (*Hoplocampa*) *orbitalis:* Sheath 148

XXV. Fig. 1.—*Hoplocampa* (*Hoplocampa*) *alpestris:* Male, anterior wing. Fig. 2.—*Hoplocampa* (*Hoplocampa*) *halcyon:* Male, anal cell of fore wing. Fig. 3.—*Hoplocampa* (*Hoplocampa*) *montanicola:* Female, four basal antennal joints. Fig. 4.—*Hoplocampa* (*Hoplocampa*) *nevadensis:* Female, four basal antennal joints. Fig. 5.—*Hoplocampa* (*Hoplocampa*) *occidentalis:* Male antenna. Fig. 6.—*Hoplocampa* (*Hoplocampa*) *montanicola:* Male antenna 148

XXVI. Fig. 1.—*Hoplocampa* (*Hoplocampa*) *flava:* Female, radial area in fore wing. Fig. 2.—*Hoplocampa* (*Hoplocampa*) *halcyon:* Female, radial area in fore wing. Fig. 3.—*Hoplocampa* (*Hoplocampa*) *montanicola:* Female, radial area in fore wing. Fig. 4.—*Hoplocampa* (*Macgillivrayella*) *lacteipennis:* Female, radial area in fore wing 148

XXVII. Dorsal aspect of heads of representative larvæ of each family of Cerambycoidea: A, *Prionus;* B, *Tetropium;* C[1], *Cyrtomerus;* C[2], *Phœnicus;* D, *Liopus;* E, *Rhagium* 152

TEXT FIGURES.

FIG. 1. *Pissodes strobi:* Head, ventral aspect, and mouth parts 13
2. *Pissodes strobi:* Head, dorsal aspect, and mandibles 14
3. *Dendroctonus valens:* Head, dorsal and lateral aspects 15
4. *Dendroctonus valens:* Head, ventral aspect, and mouth parts 16
5. *Pissodes sitchensis:* Head of larva, dorsal aspect 23
6. *Pissodes sitchensis:* Head of larva, ventral aspect 24
7. *Pissodes sitchensis:* Head of larva, lateral aspect 25
8. *A. Pissodes piperi:* Front of head of larva 26
B. Pissodes nemorensis: Front of head of larva 26
9. *Pissodes fraseri:* Lateral aspect, showing method of determining individual index 28
10. Map of the world, showing the distribution of the genus *Hoplocampa* ... 140

ERRATA

Page 7, line 12, for *cembræ* read *cembra.*
Page 34, line 16, for *deodaræ* read *deodara.*
Page 36, line 37, for *Le Conte* read *Randall.*
Page 74, line 29, after *Can. Ent.* insert *vol. 40.*
Page 102, line 29, after *n.* insert *n.*
Page 131, line 28, for *cinerius* read *cinereus.*

TECHNICAL SERIES, NO. 20, PART I.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, Entomologist and Chief of Bureau.

TECHNICAL PAPERS ON MISCELLANEOUS FOREST INSECTS.

I. CONTRIBUTIONS TOWARD A MONOGRAPH OF THE BARK-WEEVILS OF THE GENUS PISSODES.

BY

A. D. HOPKINS, PH. D.,

In Charge of Forest Insect Investigations.

Bureau of Entomolo
JAN 10 1911
RECEIVE

ISSUED JANUARY 7, 1911.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1911.